Fat in the newborn

In 1972 I received the improbable message that Douglas Gairdner wanted my advice. Our only previous contact had been on editorial matters, with me in the supplicant role, although I must nearly have met him in a different supplicant role while I waited for his niece to emerge from 19 Adams Road in March 1959. But it was far from clear to me what a research fellow had to offer him. Nevertheless, the request was pursued, he really did seem to want to see me and, what was more, it was the mountain that was going to do the moving.

Eventually he arrived at the Institute of Child Health bursting with the youthful vigour most of us never had, brandishing an Ogden's tobacco tin full of stubby little needles, a sight odd enough for any narcotic investigator. It was these that were the cause of his problem because his latest research interest, which had to do with body fat, was being frustrated by his inability to obtain samples of adipose tissue from little babies through these fine needles. Being the man he is, he had sought help from the literature and may well be the only reader of my MD thesis in the Cambridge University library. At all events I was able to give him some of my 3-inch FG 12 Bell and Croyden specials and, needless to say, he never looked back.

Between 1975 and 1977 Douglas published 3 papers on body fat in infancy.^{1,2,3} The first and the last, respectively on the composition of body fat in infants and on the assessment of total body fat, were incidental to the most important of this triad, which was entitled 'Size of adipose cells in infancy'. At the time the number of infants that had been studied was extremely small. Data were available on older children, but information on the earliest and perhaps most important part of the adipose cell size and number story was lacking. Douglas's contribution focused on cell size, which is what one actually observes and measures, and that, as will be seen, was a seminal influence.

Natural history of adipose cell development

Fat cells become recognisable in the human fetus only in the last trimester of pregnancy but there are few data on cell size in preterm infants and Douglas's are probably the best. At between 25 and 30 weeks of gestation the mean adipose cell diameter is between 30 and 50 μm and this increases to 50 to 80 μm by term². Site-to-site differences were apparent

from the earliest time of sampling and gluteal samples regularly contained bigger fat cells than samples taken from the abdominal wall. This discrepancy increases as children get bigger so that the site from which adipose cells are taken is of considerable importance.⁴

During the first year of life adipose cell diameter continues to increase and by one year of age gluteal fat cells are about 100 μm in diameter.⁵ As Douglas presciently remarked in a 'strictly tentative conclusion', the increase in body fat in the first year of life seems to be largely accounted for by a 5-fold increase in adipose cell volume.⁶ Fat cell number does not change during this time in normal children and fat cell size does not change afterwards, so that by 18 months the gluteal fat cell diameter is the same as in normal adults.⁷ It is now generally agreed that growth of body fat in normal persons is accommodated by increases in the size of fat cells during infancy and by increases in their numbers afterwards.

While it has been known for some time that fat cells once acquired cannot be lost, the idea that new fat cells can be formed at any time is a relatively new one^{8,9} but one which is becoming increasingly clear.¹⁰ The fact that really huge fat cells are not found in the very obese adult strongly suggests that there is a maximum fat cell size, and that when this size is reached, adipose cell replication begins.¹¹ The postulated critical size could change with age but the concept of size being the trigger to cell replication rather nicely explains the observations made on adipose cell numbers in normal infants described above and in pathological situations later in childhood and adult life.¹²

Changes in skinfold thickness and body fat with age

Many authors have been intrigued by the rapidity of the increase in skinfold thicknesses in infancy because it is so odd that suddenly at one year of age they stop increasing and indeed decrease in normal subjects. Surprisingly, it was not until 1973 that some data became available in England¹³ which were incorporated into standard charts,¹⁴ although Sweden was well ahead in this field.¹⁵ Values at birth¹⁶ are of little value as an indication of maturity,¹⁷ but the description of their increase is now fairly well established for our population. It is worth pointing out that what applies in one country may not necessarily apply elsewhere; the pattern is quite

different in Berlin, for example,¹⁸ and comparisons can be made only with great caution.

As an isolated measurement, skinfold thickness is of limited value, but to translate skinfold measurements into terms of total body fat is a useful exercise clinically. This has been done in adults¹⁹ and now that accurate methods for determining body fat are becoming available there are indications that skinfold thicknesses more accurately measure body fat in adults than do measures of body density.²⁰ In children the methodological problems of densitometry are considerable: heavy water²¹ and ⁴⁰K⁷ have been used as references for the calculation of lean body mass against which to compare skinfold thicknesses, but neither method is very satisfactory because there is so little evidence about the water and potassium content of the lean body mass in children.

In infants, whom we knew to be wetter, extrapolation from childhood values may give very dubious results, so Dauncey *et al.* used a geometrical method of calculating body fatness in infants.³ Their formula stands up well to refined techniques of measuring body fatness, such as using xenon.²² For practical purposes we can assume that a combination of skinfold thickness measurements gives a good indication of body fatness in infants²³ and I do not think that any serious study on nutrition in children in 1979 can afford to omit the measurement of skinfold thickness. Weight and weight-for-height indices are indirect measurements of nutritional status and are unreliable as indicators of body fatness in children^{24,25} and adults.^{20,26,27} We would be better without them.

Determinants of body fatness in infancy

Knowledge about the determinants of fatness is sparse both in children and adults. One of the classical ways of looking at genetic and environmental contributions to the determination of a characteristic is to compare monozygotic with dizygotic twins, but it seems likely that in body fatness this model has served us badly. Studies of both normal²⁸ and obese²⁹ twins have suggested a strong genetic contribution to body fatness, but placing reliability upon differences between twins depends on monozygotic and dizygotic twins being treated alike. If like-twins are treated more alike just because they look alike, a spuriously high correlation will be generated between them and the reverse could apply to dizygotic twins. There is evidence to suggest that identical twin pairs share more environmental factors in common than non-identical twins.^{30,31} This has almost certainly

affected the calculations on determinants of body fat. Hawk and Brook showed that siblings resemble each other hardly at all, while monozygotic twins resemble each other closely, and dizygotic twins are intermediate.³² Neither we, nor Mueller and Titcombe found midparent-offspring correlations to be higher than individual parent-offspring correlations, which one would certainly expect in a genetically-determined characteristic.³³ At the time of writing the balance of evidence suggests that body fatness is largely determined by environmental factors.

These data are extremely hard to obtain and are not yet available for infants. The fact that fatter mothers have fatter babies³⁴ would fit with any theory of determination of body fatness and I am inclined to think that what Hawk and Brook showed for adults is likely to apply in infancy.³²

Implications

With body fatness contributing significantly to the major risk factors for arteriosclerosis (hypertension, reduced glucose tolerance, carbohydrate induced hyperlipidaemia, lack of exercise), although it is not now itself considered a risk factor,³⁵ much interest has arisen about whether body fatness tracks. Do fat babies stay fat? Are the seeds of adult fatness sown in childhood?

It has been difficult to answer such questions, not least because people will weigh babies rather than measure how fat they are. This is bound to cause problems, since weight is mainly determined by height and overfeeding before weaning increases height.³⁶ I accept that babies whose weights reach the 90th centile during the first 6 months may have an increased risk of obesity later³⁷ and that famine in infancy may 'protect' against obesity,³⁸ but to argue from these huge retrospective studies that weight gain in infancy is the major determinant of body fatness in childhood is not supported by the facts obtained from measurements of skinfold thickness.³⁹ Nor do our recent data suggest that body fatness tracks reliably into adult life either for individuals of normal fatness or for those whose skinfold thicknesses in childhood were above the 75th centile.⁴⁰

It is important to note that a number of skinfolds need to be measured to express opinions about changes in body fatness over a number of years, because fat distribution changes markedly with advancing age as the Table shows. A combination of skinfold thicknesses gives the best indication of body fatness¹⁹ and the least between-observer error.^{41,42}

Our family data support the idea that body fatness is largely environmentally determined at all

Table Percentage increases in skinfold thickness with age (6-70 years)

	Males	Females
Triceps	50	150
Biceps	25	66
Subscapular	250	233
Suprailiac	400	220

Data from Hawk (1978).³¹

ages and our longitudinal data suggest that some individuals carry with them into adult life the habits of their childhood, while others, left to their own devices, do not.

Conclusion

Body fat appears in infants through the accumulation of fat in already existing fat cells. Overfeeding causes fat cell hypertrophy which is probably the trigger for fat cell replication at any time of life. Some periods of rapid change could be more sensitive in this respect than others. Once formed, fat cells persist, but neither their size nor their number has been shown to determine levels of fatness. Fatness in adults and children appears to be largely environmentally determined. Evidence that childhood skinfold thicknesses predict well from values in infancy or adult values from childhood ones is lacking. Obesity is bad for adults and children, but greatness cannot be said to be thrust upon them.

References

- Widdowson, E. M., Dauncey, M. J., Gairdner, D. M. T., Jonxis, J. H. P., and Pelikan-Filipkova, M. (1975). Body fat of British and Dutch infants. *British Medical Journal*, **1**, 653-655.
- Dauncey, M. J., and Gairdner, D. (1975). Size of adipose cells in infancy. *Archives of Disease in Childhood*, **50**, 286-290.
- Dauncey, M. J., Gandy, G., and Gairdner, D. (1977). Assessment of total body fat in infancy from skinfold thickness measurements. *Archives of Disease in Childhood*, **52**, 223-227.
- Duckerts, M., and Bonnet, F. (1973). Adipose cell size differences related to the site of adipose tissue biopsy in children. *Biomedicine*, **19**, 214-216.
- Bonnet, F. P., Duckerts, M., and Heuskin, A. (1976). Subcutaneous adipose tissue growth in normal and obese children: methodological problems. In *The Adipose Child*, pp. 104-111. Edited by Z. Laron and Z. Dickerman. Karger: Basel.
- Gairdner, D., and Dauncey, M. J. (1974). The effect of diet on the development of the adipose organ. *Proceedings of the Nutrition Society*, **33**, 119-121.
- Häger, A., Sjöström, L., Arvidsson, B., Björntorp, C., and Smith, U. (1977). Body fat and adipose tissue cellularity in infants: a longitudinal study. *Metabolism*, **26**, 607-614.
- Kirtland, J., Gurr, M. I., Saville, G., and Widdowson, E. M. (1975). Occurrence of pockets of very small cells in adipose tissue of the guinea pig. *Nature*, **256**, 723-724.
- Ashwell, M. A., Priest, P., and Sowter, C. (1975). Importance of fixed sections in the study of adipose tissue cellularity. *Nature*, **256**, 724-725.
- Greenwood, M. R. C., Gruen, R., and Cleary, M. P. (1978). Adipose tissue growth and the development of fat cells. In *Recent Advances in Obesity Research*, volume 2, pp. 169-189. Edited by G. A. Bray. Newman: London.
- Ashwell, M. A., Priest, P., and Bondoux, M. (1975). Adipose tissue cellularity in obese women. In *Recent Advances in Obesity Research*, volume 1, pp. 74-77. Edited by A. N. Howard. Newman: London.
- Brook, C. G. D. (1972). Evidence for a sensitive period in adipose cell replication in man. *Lancet*, **2**, 624-627.
- Hutchinson-Smith, B. (1973). Skinfold thickness in infancy in relation to birthweight. *Developmental Medicine and Child Neurology*, **15**, 628-634.
- Tanner, J. M., and Whitehouse, R. H. (1975). Revised standards for triceps and subscapular skinfolds in British children. *Archives of Disease in Childhood*, **50**, 142-145.
- Karlberg, P., Engstrom, I., Lichtenstein, H., and Svenneberg, I. (1968). The development of children in a Swedish urban community. A prospective longitudinal study. III. Physical growth during the first three years of life. *Acta paediatrica Scandinavica*, Supplement 187, 48-66.
- Oakley, J. R., Parsons, R. J., and Whitelaw, A. G. L. (1977). Standards for skinfold thickness in British newborn infants. *Archives of Disease in Childhood*, **52**, 287-290.
- Farr, V. (1966). Skinfold thickness as an indication of maturity of the newborn. *Archives of Disease in Childhood*, **41**, 301-308.
- Schluter, K., Funck, W., Pachaly, J., and Weber, B. (1976). Development of subcutaneous fat in infancy. *European Journal of Pediatrics*, **123**, 255-267.
- Durnin, J. V. G. A., and Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness; measurements in 481 men and women aged 16-72. *British Journal of Nutrition*, **32**, 77-97.
- Womersley, J., and Durnin, J. V. G. A. (1977). A comparison of the skinfold method with extent of 'overweight' and various weight-height relationships in the assessment of obesity. *British Journal of Nutrition*, **38**, 271-284.
- Brook, C. G. D. (1971). Determination of body composition of children from skinfold measurements. *Archives of Disease in Childhood*, **46**, 182-184.
- Mettau, J. W., Degenhart, H. J., Visser, H. K. A., and Holland, W. P. S. (1977). Measurement of total body fat in newborns and infants by absorption and desorption of non-radioactive xenon. *Pediatric Research*, **11**, 1097-1101.
- Whitelaw, A. G. L. (1977). Subcutaneous fat in newborn infants of diabetic mothers; an indication of quality of diabetic control. *Lancet*, **1**, 15-18.
- Newens, E. M., and Goldstein, H. (1972). Height, weight, and the assessment of obesity in children. *British Journal of Preventive and Social Medicine*, **26**, 33-39.
- Garn, S. M., Clark, D. C., and Guire, J. (1975). Growth, body composition, and development of obese and lean children. In *Childhood Obesity*, pp. 23-47. Edited by J. Winick. Wiley: New York.
- Seltzer, C. C., Stoudt, H. W., Bell, B., and Mayer, J. (1970). Reliability of relative body weight as a criterion of obesity. *American Journal of Epidemiology*, **92**, 339-350.
- Goldbourt, U., and Medalie, J. H. (1974). Weight-height indices. *British Journal of Preventive and Social Medicine*, **28**, 116-128.
- Brook, C. G. D., Huntley, R. M. C., and Slack, J. (1975). Influence of heredity and environment in the determination of skinfold thickness in children. *British Medical Journal*, **2**, 719-721.
- Borjeson, M. (1976). The aetiology of obesity in children. *Acta paediatrica Scandinavica*, **65**, 279-287.

- ³⁰Smith, R. T. (1965). A comparison of socio-environmental factors in monozygotic and dizygotic twins. Testing an assumption. In *Methods and Goals in Human Behaviour Genetics*, pp. 45–61. Edited by S. G. Vandenberg. Academic Press: London.
- ³¹Hawk, L. J. (1978). Determinants of body fatness. MD thesis, University of Edinburgh.
- ³²Hawk, L. J., and Brook, C. G. D. (1979). Family resemblances of height, weight, and body fatness. *Archives of Disease in Childhood*, **54**, 877–879.
- ³³Mueller, W. H., and Titcombe, M. (1977). Genetic and environmental determinants of growth of school age children in a rural Columbian population. *Annals of Human Biology*, **4**, 1–15.
- ³⁴Whitelaw, A. G. L. (1976). Influence of maternal obesity on subcutaneous fat in the newborn. *British Medical Journal*, **1**, 985–986.
- ³⁵Shaper, A. G., and Marr, J. W. (1977). Dietary recommendations for the community towards the postponement of coronary heart disease. *British Medical Journal*, **1**, 867–871.
- ³⁶Widdowson, E. M., and McCance, R. A. (1960). Some effects of accelerating growth. *Proceedings of the Royal Society, Series B*, **152**, 188–206.
- ³⁷Charney, E., Goodman, H. C., McBride, M., Lyon, B., and Pratt, R. (1976). Childhood antecedents of adult obesity. *New England Journal of Medicine*, **295**, 6–9.
- ³⁸Ravelli, G.-P., Stein, Z. A., and Susser, M. W. (1976). Obesity in young men after famine exposure *in utero* and early infancy. *New England Journal of Medicine*, **295**, 349–353.
- ³⁹Poskitt, E. M. E., and Cole, T. J. (1977). Do fat babies stay fat? *British Medical Journal*, **1**, 7–9.
- ⁴⁰Hawk, L. J., and Brook, C. G. D. (1979). Influence of body fatness in childhood on fatness in adult life. *British Medical Journal*, **1**, 151–152.
- ⁴¹Burkinshaw, L., Jones, P. R. M., and Krupowicz, D. W. (1973). Observer error in skinfold measurements. *Human Biology*, **45**, 273–279.
- ⁴²Womersley, J., and Durnin, J. V. G. A. (1973). An experimental study on variability of measurements of skinfold thickness in young adults. *Human Biology*, **45**, 281–292.

C. G. D. BROOK
 Department of Paediatrics,
 The Middlesex Hospital,
 Mortimer Street,
 London W1N 8AA