Studies of Growth of Australian Infants

Michael Gracey and Nancy E. Hitchcock

Gastroenterology and Nutrition Research Unit, Princess Margaret Children's Medical Research Foundation (Inc.), and Department of Child Health, University of Western Australia, Perth, Western Australia 6001

While we now possess a fairly accurate and extensive knowledge of the normal curve of growth of certain animals, particularly the white rat and the white mouse, it is a regrettable fact that we are not yet in possession of equally reliable and extensive data concerning the growth of human beings.

T. Brailsford Robertson, 1916 (1)

There is disagreement about what is normal growth in infancy. This is an important issue because "normal" growth charts are used extensively in clinical pediatrics and in public health work to assess the nutritional status of individuals, groups, communities, and countries. There is also disagreement about the relevance of widely used British and American growth charts to other populations. This applies in Australia where the National Health and Medical Research Council (NHMRC) is currently considering whether to undertake a nationwide study to determine local "standards" or whether international values can be used. In some countries, local and international standards are used, sometimes applied to different sections of the population.

There is also some controversy about the dietary patterns and nutrient intakes required to achieve normal growth in early life. In Australia, one of the most basic tools used by dietitians and nutritionists to assess adequate nutrient intakes is the dietary allowances for use in Australia (2). These are used as reference points for an initial assessment of the adequacy of diets of individuals or groups within the community. They were referred to in our own work, for example, when we claimed that the dietary patterns of aborigines (3) or children of migrants (4) were "inadequate" or "unsatisfactory" when compared with these allowances. They are also used as a basis for designing diets for individuals with a wide variety of problems, including obesity, diabetes, hypertension, and other metabolic disorders, as well as for people receiving institutional foods.

The Australian dietary allowances have been revised several times, the latest revision being in 1971 (2). Many of the recommendations in these Australian allowances were based on interpretations of the FAO/WHO expert group reports (5) on requirements for some nutrients. The values for food energy for infants and for children aged 2 to 11 years were obtained from Australian data on food
consumption, which were based on Australian studies by Roche and Cahn (6); the data for 2-year-olds were obtained in 1954. The figures for infants were those summarized by Clements (7). Where no Australian data were available for various age groups, recommendations were extrapolated. It seems obvious that these recommendations, currently in use across Australia, contain serious inaccuracies, particularly for young children, in view of the significant differences in lifestyle, breastfeeding patterns, and eating and drinking habits which prevail today in contrast to those in vogue in the 1940s and 1950s when those data were obtained.

There are very few comprehensive, contemporary, longitudinal studies combining assessment of diet, nutrition, and growth of healthy children in early life. The Perth Growth Study (PGS) was designed with this in mind in order to document normal patterns in a well-defined sample of healthy infants in a well-nourished population. The study began in 1979 with a group of more than 200 apparently healthy infants born in the city of Perth, Australia. At the time of this writing the subjects are aged 4 years, and the study is due to continue until they are 5 years old. This chapter discusses the findings of the PGS up to early 1983 and how these relate to other studies of growth and nutrition in Australian infants. The findings then are compared to recent international literature, with particular reference to the use of growth charts to assess nutrition and growth performance in early life.

EARLIER AUSTRALIAN CHILD GROWTH STUDIES

Historically, studies of growth of Australian infants fall into three periods: (a) before 1920, when overseas data were the only ones available and were used to assess the growth of children in Australia; (b) 1920s to 1970s, when several attempts were made to develop Australian growth standards; and (c) since the late 1970s, when serious consideration has been given to the adoption of international reference values.

Brailsford Robertson (1,8) was the first to publish an Australian infant growth study, done about 1915. This study of more than 150 infants in the state of South Australia led the author to suggest that British charts, widely used in Australia at the time, were inappropriate for Australian conditions. The Australian infants were heavier at birth and their “superiority of bodily dimensions” was maintained in the first year. As the Australian community was then overwhelmingly British in origin, this change in growth in infancy was attributed to improved “climatic, social and economic conditions.”

In 1926, Southby (9) described a standard which he considered “representative of the ordinary well developed, local baby” from a study of 2,000 subjects drawn from normal births (excluding twins) in an obstetric hospital, children discharged from a children's hospital, competitors in the “Empire Baby Competitions” of 1924, and competitors in a baby show. Not surprisingly, these children were heavier and grew faster than growth charts in use at that time suggested. Despite the bias inherent in the selection of these subjects, the author proposed the development of a local Australian standard for growth. It should be noted that Southby’s study
was cross-sectional, and the sexes were not separated. A later study of 700 infants in the state of Victoria by Scantlebury (10) also combined the results for boys and girls.

Clements (11) reported a study in 1933 designed to document normal growth patterns for Australian infants. This was a retrospective analysis of weights recorded every 2 weeks from more than 1,000 infants in baby health care centers in the state of New South Wales. They were selected to be representative of Sydney's population of the time and covered the first 12 months of life. Excluded were (a) inadequate records, (b) premature babies, (c) multiple births, and (d) subjects with illnesses during the year.

This was an outstanding study, for its day, and still provides important information about normal growth in early life. Clements compared his findings to those of earlier Australian and overseas studies; his results were remarkably similar to the earlier Australian reports already mentioned (8,10). Clements' figures were adopted for use in baby health care centers in the state of New South Wales and now provide a valuable reference for more recent studies.

Dale (12) undertook a cross-sectional study from 1936 to 1946. It was the first in Australia to document weight gains in the first 5 years of life. These data were subsequently used in the first Australian growth charts in 1957 (12). The Melbourne University Child Growth Study Unit began a major longitudinal study in the 1950s to assess the dynamics of growth. Their subjects were born between 1951 and 1953, and data were taken quarterly between 2 and 4 years of age and biannually thereafter. The 0- to 2-year period was not studied. This was a comprehensive, multidisciplinary study involving specialists in anatomy, anthropology, child health, dentistry, orthodontics, nutrition, and psychology (13). Particular emphasis was given to patterns of development of skeletal maturity. A later study in Melbourne (14) led the authors to comment:

The indications appear to be for regular upgrading of the Australian standards and the data gathered must represent wide population groups, thus allowing assessments certainly with comparable birth or generation age and ideally for select population and racial groupings. The necessity for nonreliance on overseas standards needs stressing and also an appreciation of the inherent errors in comparing assessments of different population groups.

We believe these comments represent an unrealistic approach to variations in normal growth in a relatively small, ethnically diverse population like ours. The Melbourne Child Health Study data have not been used in Australian growth charts.

Bell and Lay (15) undertook a study of more than 1,000 subjects in the 1960s in baby health centers in New South Wales; this provides important comparisons with the earlier study by Clements (11). About one-third of subjects from Bell and Lay's study were from country centers. As in Clements' study, the records were examined every 2 weeks in the first 12 months of life. Their findings, which showed accelerated growth velocity (for weight) in comparison with 1933, are shown below
in relation to Clements’ work and our current PGS. It is of interest to read that the increased weight gains found in 1964 were thought to be due to “a general rise in the standards of living in the lower economic groups with an improved diet and a recession of diseases” when compared to the work of Clements, which was conducted during the great depression. We suspect that the decline of breastfeeding and the popularity of bottle feeding in the 1960s were the important determinants of this trend to more rapid weight gains, which we now consider undesirable.

Jones and Hemphill (16) published the first comprehensive survey of physical measurements of infants and preschool children in New South Wales in 1974. This was a cross-sectional study of height, weight, biacromial diameter, subscapular skinfold thickness, head circumference, and length of 16,000 infants and preschool children attending “virtually all baby health centres” in Sydney in 1971–1972. A large number of preschool kindergartens were also visited. Recognizing the bias inherent in their method of sampling, the authors include former attenders at child health centers as well. Their ethnic origins were roughly grouped as: (a) Australian-born of Australian parents, (b) Australian-born of Southern European parents (e.g., Greece, Italy, Spain), and (c) Australian-born of other European parents.

The authors concluded that:

Height increases steadily with age in the pre-school period, with no very obvious change in the pattern as occurs at puberty. The same applies to weight... there was little difference between the various groups classified by national origin, and only a suggestion that children born in Australia with Southern European parents were heavier than Australians from 3 years of age.

They commented on the paucity of earlier Australian studies, acknowledged that the work of Clements (11) was the best available then, and that there had been “an increase in weight for all ages since then.” The data gathered by Jones and Hemphill (16) were used to construct the “Charts and tables of heights, masses and head circumferences of infants and children” (17), which are the current national charts used in Australia.

The Tasmanian child growth surveys done over the past decade have also provided important information about Australian children. These have been compared with other Australian studies, including those of Clements (11) and Bell and Lay (15). While the increased weight gains found by the latter had been interpreted as a healthy trend reflecting improved living standards and diet, the Tasmanian study found more evidence of that trend (18) but attributed it to overweight. There was then increasing concern at the extent of childhood obesity in the Australian community. The Tasmanian experience suggested that the incidence of obesity in Australian children was increasing and, as in Britain (19), may have been due to overfeeding in the first years of life. Court et al. (20) found elevated diastolic blood pressures in more than half their obese children studied in Melbourne. This was considered relevant to the development of coronary heart disease in later life, which is a major problem in Australia and similar Western countries. Godfrey and his colleagues (21) found serum cholesterol levels in children in the Western Australian
town of Busselton (see Fig. 1) to be higher than in most reported studies and that a significant proportion of their subjects had hypercholesterolemia.

It was becoming evident that nutritionally related disorders were not uncommon in our society. Lewis, a participant in the Tasmanian child growth surveys, had commented that "few people appear to be interested in nutrition in Australia" (22). At that time, our NHMRC did not classify nutrition as a discipline for research studies.

It was against this background and with these gaps in our knowledge of human nutrition in Australia that the PGS was commenced in 1979 (23). The period from 0 to 2 years seemed most important to study, as little local information was available concerning this crucial period.

FIG. 1. Map of Australia (top) and southwest Australia (bottom) showing the locations of Perth and Busselton. (From Hitchcock and Gracey, ref. 3.)
LOCAL CONDITIONS

Australia is an affluent, industrialized nation whose infants and young children should be well nourished. Childhood undernutrition is almost unknown, and the nutritional impact of infectious disease is insignificant, except for vulnerable, disadvantaged groups, which include aborigines, the children of recently arrived migrants, and those from lower socioeconomic classes and unstable families. European settlement began just under 200 years ago, and the current population of 15 million is predominantly European, particularly of British origin. Postwar migration has added substantial numbers of Southern and Eastern Europeans and Southeast Asians in the past 30 years. The population is largely urban, and the largest cities, Sydney, Melbourne, Perth, Adelaide, and Brisbane, are coastally located state capitals containing most of the nation's people.

The PGS reported here is being undertaken in Perth. This city of 900,000 people is the state capital of Western Australia. Although it has only 1.3 million people, it covers 2.4 million square kilometers, the western third of the continent. The climate is typically Mediterranean, with hot, dry summers and wet, mild winters. The food supply is abundant, varied, well organized, and mostly of local origin. Most families shop at large, well-stocked supermarkets, many of which belong to large corporations and all of which are required to meet high standards of food quality and hygiene. In these respects, Australia resembles other Western countries where there have been important changes in food supplies and distribution over the past three to four decades.

Important changes in lifestyle have occurred in Australia and similar countries through the influence of urbanization, automation, and the media. These have probably had significant effects on dietary patterns in the first few years of life, when eating habits are being formed. Another recent trend of relevance to infant nutrition that has emerged in Australia and other industrialized countries is a resurgence of breastfeeding.

THE PERTH GROWTH STUDY

In mid-1979, 104 boys and 101 girls were entered into the PGS. They were selected randomly from metropolitan Midwife Notification of Birth Records kept by the Western Australian Public Health Department. The criteria for selection were that the subjects were: (a) at least second-generation Australian-born, but excluding aborigines; (b) from two-parent families; (c) full-term, single births from uncomplicated pregnancies and deliveries; (d) weighed 2,500 g or more at birth; and (e) living within 12 km of the Perth General Post Office.

These selection criteria were used to choose a sample of manageable size for detailed, long-term dietary and growth studies and to identify them as an apparently “normal” local group. This is important in Australia because of the recently emerging ethnic diversity of our population.
Collection of Data

Birthweight and birth length measurements were available from midwife records. Head circumference at birth, not a routine measurement in all hospitals, was not available in some cases. Measurements of length, body weight, and head circumference of infants have been recorded at 6 weeks of age, and at 3, 6, 9, and 12 months during the first year of life, using standard methods (17).

Information was obtained from the mother by interview, when her infant was 6 weeks of age, concerning the kind and frequency of milk feeding and the kind, amount, and frequency of nonmilk foods consumed by her infant. At all later times, an accurate record of all food and drink consumed by the infant was kept by the mother for 7 consecutive days prior to the day when physical measurements were made. This allowed cross-checking of the record at that time. If the mother was breastfeeding, she recorded the fact and the duration of each feed. Anthropometric and dietary data have been obtained at 3, 6, 9, 12, and 18 months and at 2 and 3 years of age. The study is scheduled to continue until the children are 5 years old.

In addition to anthropometric and dietary data for each infant, information is available from the parents of each child concerning parents’ educational achievements and occupations, age, weight, and height of each parent, number of children in the family, and mother’s habits of smoking and consuming alcohol during pregnancy and after the infant’s birth. Each mother has kept a record in a booklet supplied to her of the major developmental milestones of her infant, and notes about timing of eruption of teeth and any illnesses.

Anthropometric Findings

The mean weights and lengths (up to 24 months) or heights of the subjects from birth to 3 years are shown in Table 1.

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th></th>
<th></th>
<th>Girls</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td></td>
<td></td>
<td>Girls</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>Weight</td>
<td>Length</td>
<td>n</td>
<td>Weight</td>
<td>Length</td>
</tr>
<tr>
<td>Birth</td>
<td>104</td>
<td>3.56 ± 0.04</td>
<td>51.9 ± 0.2</td>
<td>101</td>
<td>3.47 ± 0.04</td>
<td>50.7 ± 0.2</td>
</tr>
<tr>
<td>6 weeks</td>
<td>95</td>
<td>4.81 ± 0.06</td>
<td>56.3 ± 0.2</td>
<td>96</td>
<td>4.60 ± 0.05</td>
<td>55.5 ± 0.2</td>
</tr>
<tr>
<td>3 months</td>
<td>99</td>
<td>5.92 ± 0.08</td>
<td>60.7 ± 0.2</td>
<td>96</td>
<td>5.61 ± 0.06</td>
<td>59.3 ± 0.2</td>
</tr>
<tr>
<td>6 months</td>
<td>95</td>
<td>7.85 ± 0.09</td>
<td>67.5 ± 0.3</td>
<td>94</td>
<td>7.44 ± 0.08</td>
<td>65.9 ± 0.2</td>
</tr>
<tr>
<td>9 months</td>
<td>88</td>
<td>9.11 ± 0.10</td>
<td>72.1 ± 0.3</td>
<td>90</td>
<td>8.56 ± 0.09</td>
<td>70.6 ± 0.2</td>
</tr>
<tr>
<td>12 months</td>
<td>85</td>
<td>10.01 ± 0.11</td>
<td>75.9 ± 0.3</td>
<td>88</td>
<td>9.50 ± 0.10</td>
<td>74.9 ± 0.2</td>
</tr>
<tr>
<td>18 months</td>
<td>80</td>
<td>11.60 ± 0.12</td>
<td>82.7 ± 0.3</td>
<td>79</td>
<td>10.93 ± 0.12</td>
<td>81.7 ± 0.3</td>
</tr>
<tr>
<td>24 months</td>
<td>77</td>
<td>12.78 ± 0.15</td>
<td>88.5 ± 0.4</td>
<td>78</td>
<td>12.19 ± 0.14</td>
<td>87.6 ± 0.3</td>
</tr>
<tr>
<td>30 months</td>
<td>78</td>
<td>13.77 ± 0.14</td>
<td>92.8 ± 0.4</td>
<td>79</td>
<td>13.27 ± 0.14</td>
<td>91.9 ± 0.3</td>
</tr>
<tr>
<td>36 months</td>
<td>76</td>
<td>14.89 ± 0.17</td>
<td>96.9 ± 0.4</td>
<td>76</td>
<td>14.35 ± 0.17</td>
<td>95.9 ± 0.3</td>
</tr>
</tbody>
</table>

*Mean values, kg ± SEM.
*Mean values, cm ± SEM.
Breastfeeding

Breastfeeding patterns in the first 12 months are shown in Table 2 in relation to social rank using a 4-point local scale (24). The highest (A) includes professionals, e.g., doctors and lawyers; the lowest (D) are unskilled workers. Three-quarters of our sample were from middle-class families (B and C), which reflects the overall distribution of the general Australian population using Congalton’s (24) method of assessment of social class.

Most mothers breastfed their babies, particularly those from the upper social ranks. Only 8% of mothers who breastfed their infants gave them complementary feeds. Low-solute (so-called “humanized”) formulas\(^1\) were given to most infants who were not breastfed until 6 months of age; after that, these formulas were used less, and cow’s milk consumption increased.

### Introduction of Nonmilk Food

By 6 weeks of age, 10% of infants were being given some nonmilk foods. The foods given were mainly fruit juice and syrups with vitamin C sweetened with sugar or sorbitol. Cereals and sweet biscuits were used, particularly for formula-fed babies. By 3 months of age, about one-third of infants were having nonmilk food. During the first 6 months, nonmilk foods (or solids) were more prevalent with the formula-fed infants. At 6 months, 8 infants were still being solely breastfed; all the others were being given a variety of foods, except cereals and fruit syrups. After 6 months, commercially made meats and broths, fruit gels, yogurts, and other desserts were popular (25).

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**TABLE 2. Percentage of infants breastfed\(^a\)**

<table>
<thead>
<tr>
<th>Age</th>
<th>Percentage of total sample</th>
<th>Percentage of each social group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>6 weeks</td>
<td>83</td>
<td>96</td>
</tr>
<tr>
<td>3 months</td>
<td>77</td>
<td>96</td>
</tr>
<tr>
<td>(13 weeks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>64</td>
<td>88</td>
</tr>
<tr>
<td>(26 weeks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 months</td>
<td>46</td>
<td>68</td>
</tr>
<tr>
<td>(39 weeks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 year</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>(52 weeks)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)From ref. 23.
\(^b\)Highest A → lowest D.

\(^1\)Examples: Lactogen and Nan, Nestlé Company (Australia), Sydney; and SMA, S26, Wyeth Pharmaceuticals Pty. Ltd., Sydney.
Dietary Energy and Nutrient Intakes

Dietary energy and nutrient intakes from foods other than breast milk were calculated from 7-day records of food intake. After detailed instruction, these were kept by the mothers in household measures and checked with her carefully before the calculations were done. The record sheets were manually converted to quantitative metric measures, and calculations were made using a computer program based on "tables of composition of Australian foods" (26) and, where appropriate, on analyses of food supplied by manufacturers. Direct estimates of breast milk consumption were not done in this study. The mean total energy intakes of infants up to 6 months of age were estimated from energy requirements calculated for maintenance and growth (27). These estimates give an acceptable guide to total dietary energy intake up to this age.

At 6 weeks of age, intakes for boys were, on the average, 2,300 kJ/day and for girls 2,135 kJ/day. At 3 months, these rose to 2,570 kJ/day for boys and 2,430 kJ/day for girls. At 6 months, the figures were 3,100 kJ/day and 2,930 kJ/day respectively (28). Dietary energy intakes for subjects not breastfed later were 3,745 ± 95 kJ/day (boys) and 3,620 ± 100 kJ/day (girls) at 9 months and 4,145 ± 108 kJ/day (boys) and 3,975 ± 105 kJ/day (girls) at 12 months of age (28). By 2 years of age, daily dietary energy intakes were 5,350 ± 117 kJ (boys) and 4,850 ± 138 kJ (girls). At 3 years of age, they were 5,740 ± 117 and 5,553 ± 111 kJ, respectively, for boys and girls (29). Intakes of major nutrients from 9 months to 3 years of age are shown in Table 3. Intakes of some minerals and vitamins are shown in Table 4.

### Table 3. Mean daily intakes of major nutrients

<table>
<thead>
<tr>
<th>Age</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Carbohydrate (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 months</td>
<td>33.8 ± 1.2</td>
<td>42.7 ± 1.8</td>
<td>103.4 ± 3.3</td>
</tr>
<tr>
<td>12 months</td>
<td>38.5 ± 1.4</td>
<td>42.5 ± 1.6</td>
<td>115.9 ± 3.1</td>
</tr>
<tr>
<td>18 months</td>
<td>43.1 ± 1.1</td>
<td>50.5 ± 1.3</td>
<td>142.1 ± 3.7</td>
</tr>
<tr>
<td>2 years</td>
<td>43.6 ± 1.3</td>
<td>54.1 ± 1.6</td>
<td>146.9 ± 3.9</td>
</tr>
<tr>
<td>3 years</td>
<td>46.3 ± 1.2</td>
<td>57.1 ± 1.4</td>
<td>174.1 ± 4.3</td>
</tr>
<tr>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 months</td>
<td>32.8 ± 1.4</td>
<td>39.6 ± 1.5</td>
<td>95.0 ± 2.8</td>
</tr>
<tr>
<td>12 months</td>
<td>38.1 ± 1.3</td>
<td>42.4 ± 1.5</td>
<td>103.5 ± 3.4</td>
</tr>
<tr>
<td>18 months</td>
<td>39.9 ± 1.4</td>
<td>46.3 ± 1.5</td>
<td>126.0 ± 3.8</td>
</tr>
<tr>
<td>2 years</td>
<td>40.9 ± 1.3</td>
<td>50.0 ± 1.5</td>
<td>143.6 ± 4.0</td>
</tr>
<tr>
<td>3 years</td>
<td>44.7 ± 1.2</td>
<td>57.2 ± 1.4</td>
<td>163.9 ± 3.6</td>
</tr>
</tbody>
</table>

Food Consumption Patterns

Apart from estimating the amounts of dietary energy and nutrients consumed by subjects in this study, we have assessed the development of patterns of consumption of dietary components (solids and fluids) in these children. We found that solids were negligible sources of dietary energy at 6 weeks, provided only 2% at 3 months and 22% at 6 months, and, by 9 months of age, provided almost 50%
TABLE 4. Mean daily intakes of some minerals and vitamins

<table>
<thead>
<tr>
<th>Age</th>
<th>Calcium (mg)</th>
<th>Iron (mg)</th>
<th>Thiamine (</th>
<th>xg)</th>
<th>Riboflavin (mg)</th>
<th>Niacin (mg)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 months</td>
<td>790 ± 39</td>
<td>7.0 ± 0.7</td>
<td>786 ± 49</td>
<td>1.6 ± 0.07</td>
<td>6.4 ± 0.6</td>
<td>62.9 ± 6.3</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>781 ± 38</td>
<td>5.7 ± 0.3</td>
<td>822 ± 41</td>
<td>1.6 ± 0.07</td>
<td>7.0 ± 0.6</td>
<td>65.8 ± 5.0</td>
<td></td>
</tr>
<tr>
<td>18 months</td>
<td>755 ± 31</td>
<td>6.7 ± 0.2</td>
<td>891 ± 30</td>
<td>1.6 ± 0.05</td>
<td>7.8 ± 0.3</td>
<td>73.7 ± 5.6</td>
<td></td>
</tr>
<tr>
<td>2 years</td>
<td>722 ± 29</td>
<td>6.6 ± 0.2</td>
<td>819 ± 23</td>
<td>1.4 ± 0.05</td>
<td>7.4 ± 0.3</td>
<td>68.3 ± 5.8</td>
<td></td>
</tr>
<tr>
<td>3 years</td>
<td>645 ± 23</td>
<td>7.9 ± 0.2</td>
<td>891 ± 26</td>
<td>1.4 ± 0.05</td>
<td>8.9 ± 0.3</td>
<td>66.1 ± 4.9</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 months</td>
<td>838 ± 34</td>
<td>7.5 ± 0.7</td>
<td>691 ± 31</td>
<td>1.7 ± 0.07</td>
<td>6.2 ± 0.5</td>
<td>55.3 ± 4.7</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>797 ± 34</td>
<td>5.7 ± 0.4</td>
<td>760 ± 34</td>
<td>1.6 ± 0.05</td>
<td>5.9 ± 0.3</td>
<td>45.8 ± 3.8</td>
<td></td>
</tr>
<tr>
<td>18 months</td>
<td>692 ± 33</td>
<td>5.9 ± 0.3</td>
<td>832 ± 30</td>
<td>1.5 ± 0.05</td>
<td>7.5 ± 0.4</td>
<td>68.7 ± 5.7</td>
<td></td>
</tr>
<tr>
<td>2 years</td>
<td>615 ± 32</td>
<td>6.1 ± 0.2</td>
<td>789 ± 26</td>
<td>1.3 ± 0.05</td>
<td>7.6 ± 0.3</td>
<td>69.1 ± 6.0</td>
<td></td>
</tr>
<tr>
<td>3 years</td>
<td>596 ± 26</td>
<td>7.4 ± 0.3</td>
<td>861 ± 36</td>
<td>1.4 ± 0.05</td>
<td>8.9 ± 0.4</td>
<td>63.5 ± 5.0</td>
<td></td>
</tr>
</tbody>
</table>

*This does not include vitamins and minerals from nonfood sources, e.g., medications.
²This does not include niacin obtained from dietary tryptophan.

of the dietary energy and more thereafter (25). By 12 months of age, the proportion of dietary energy provided by milk had fallen to 35%; meanwhile, the relative contributions of meat, cheese, and eggs had risen from 10 to 15% and cereals and bread from 11 to 14%.

Daily consumption of cow's milk declined from an average of 490 ml at 1 year, to 350 ml at 2 years, and 300 ml at 3 years of age. The consumption of cheese almost doubled from 7 g/day at 1 year to 12 g/day at 2 to 3 years; the lower levels of calcium consumption were largely due to the drop in milk consumption.

At 1 year of age, two-thirds of the dietary energy came from meat, fish, poultry, eggs, cereals, and milk. By 2 years, this had fallen to 50%. In the second and third years, significantly more dietary energy came from fruit juices, sugars, and sweet biscuits and cakes, which were usually eaten between meals. The habit of adding sugar to cereals was an important reason for increased sugar consumption, but most was due to the consumption of sweetened cordials, carbonated drinks, and confectionery. These trends are reflected in the threefold increase in sugar consumption between 1 and 2 years of age. It is interesting to note that 10% of children at 2 years of age received more than 20% of their total daily food energy from the "sugars" food category.

Sodium intakes were calculated from food records but excluded salt added to food during its preparation at home. Only 56% of mothers added salt to their 1-year-old infant's food (28); this was virtually unchanged for 2-year-olds. By the time their children were 3 years old, however, 72% of mothers were adding salt. The mean sodium intakes at 12 months were 54 (boys) and 52 (girls) mEq; at 2 years, 73 (boys) and 72 (girls) mEq; and at 3 years, 81 (boys) and 79 (girls) mEq (29).
DISCUSSION

The PGS has provided important new information about current feeding practices and the nutrition of Australian infants and young children. These results are relevant to continuing discussion about "growth standards" or "reference values" which are used in growth charts for clinical and public health purposes.

Three-quarters of our subjects are still taking part in the PGS 3 years after it started; we hope that nearly all of these will see the study through to its planned completion when they are 5 years of age. The geography of Perth, its demographic make-up, and the positive image of our Children's Hospital and Research Foundation with our community have helped us retain such a good proportion of participants. Being the only Children's Hospital for more than 2,000 km in what is sometimes described as the most isolated capital in the Western world has been to our advantage. We also have encouraged continued participation by sending all children specially made cards on their birthdays and by reminding mothers by mail about forthcoming interviews and the 7-day food record periods. We also offer bus fares to and from the hospital. Interviews and physical measurements are done in the large, bright, and colorful demonstration kitchen of our hospital's dietetics department. We have assiduously avoided influencing the mother's and family's attitudes to food and nutrition throughout the study. When medical or personal problems have arisen, we have been ready to arrange whatever assistance was required. Most of the dropouts from the study have been because families have moved away. Three mothers returned to fulltime work and decided to withdraw from the study; seven families were unable to be recontacted; several were "unable to cope." Overall, these dropouts have had no significant effect on the socioeconomic distribution of the group.

It could be argued that the PGS sample may not be representative of the wider Australian community. This prompted us to obtain a larger sample of infants born at the same time as PGS subjects, but from the wider community, to determine whether the findings from the Perth study reflect current trends in our community. We obtained relevant information from 704 subjects (365 boys and 339 girls) born between January 1 and June 30, 1979, who had attended 12 metropolitan and six country child health centers (Geraldton, Bunbury, Busselton, Collie, Northam, and Pinjarra). These were within 400 km of Perth and were chosen to represent all socioeconomic groups. The results of this study have been reported elsewhere (30).

The trends in infant feeding and growth in this sample were similar to the PGS results. Using multiple regression analysis with age, social class, and duration of breastfeeding as independent variables, data from the PGS and the wider study adequately fitted a single regression equation; i.e., patterns were similar in each. Just over one-third of infants in both studies were having solids by 3 months. These tended to be introduced earlier in formula-fed infants. Weights of infants in the four social groups were not significantly different at birth. By 12 months of age, however, infants from the lowest socioeconomic group (D) were significantly heavier.
than those from the highest group (A). This may be because breastfeeding was practiced least by mothers in group D. This is supported by the finding that the child health center study showed an association between social class and breastfeeding, and breastfeeding and weight gain (30). As far as can be ascertained, findings from the PGS give a reasonable indication of what is happening in our community at the present time.

**Breastfeeding**

At 6 weeks, 83% of mothers in our study were breastfeeding; by 6 months, 64% were still breastfeeding; and at 12 months, 25% of infants were still breastfed to some extent (31). This confirms an apparently widespread trend back to breastfeeding in Australia and other industrialized countries (32–35). In the mid-1960s to early 1970s, only about one-quarter of mothers in the United States and Canada breastfed (36,37). Although there has been some increase in breastfeeding rates since then, most mothers breastfeed for only short periods. Solid foods were introduced to our PGS subjects later than they would have been in Australia a decade ago and to breastfed babies later than to formula-fed infants (25). This is similar to the situation in Canada, where the median age of introduction of solids to breastfed infants is 3 months and to bottle-fed infants, 1 month (37).

**Nutrient Intakes in the First 12 Months**

The trend back to breastfeeding found in this study was accompanied by significant changes in nutrient intake patterns in these infants. Protein intakes were much less in the first 6 months of life than in earlier studies of predominantly artificially fed infants. For example, the mean daily protein intake of infants aged 6 months in 1965 (38) was 36 g, compared to the estimated 18.4 g for boys and 15.1 g for girls in this study. By 12 months of age, when mixed feeding has become well established, these differences were much less. A similar trend has been found recently in the United States (39). Sodium intakes were also down in the PGS, because of the lower sodium content of breastmilk and humanized formulas, compared to cow’s milk, and greater use of home-cooked foods (often without added salt) rather than canned baby foods (28).

Sodium intakes in this study were lower than those reported from the United States as recently as 1972 (40). This difference is attributable to the lower sodium content of breast milk and humanized formulas compared to cow’s milk and the greater use of home-cooked foods rather than canned baby foods. An increasing public awareness of the possible long-term consequences of excessive salt intake for the development of degenerative cardiovascular disease may also have contributed to these lower salt intakes. Yeung et al. (41) studied sodium intakes in their prospective study of Canadian children and related the high intakes they found after 6 months of age to the salt content of home-made foods. They recommended that salt should not be added to home-made foods, or that infants should be given canned preparations that do not contain added salt.
Growth in the First 12 Months

There are three comparable Australian studies (11, 15, 42) in which weight of infants was recorded longitudinally. These provide interesting comparisons with the results of the present study, which are shown in Table 5.

Mean birthweights in PGS subjects were similar to those found by Bell and Lay (15) in the mid-1960s, by Boulton (43) in the late 1970s, and slightly less than by Clements (11) in 1933. Median weights at 3, 6, 9, and 12 months were much greater in the 1964 sample than in the other studies; this is shown clearly in Fig. 2. Similar patterns of growth were found in more than 1,000 breastfed Australian babies surveyed by questionnaire by the Nursing Mothers Association of Australia (42). It is tempting to suggest that the increased rates of growth in the 1960s were due to the early introduction of solids and the use of cow's milk formulas with added sugar, sometimes made excessively concentrated. This occurred soon before the resurgence of breastfeeding, which is now well established in Australia.

The recent longitudinal growth study of Canadian infants done by Yeung and his colleagues (44) has many similarities, and some important differences, when compared to our study, which was done independently in Perth at about the same time. The Canadian study was undertaken in Toronto and Montreal between 1977 and 1979, initially with 403 infants, in an attempt to provide data to develop Canadian

### Table 5. Mean body weights of Australian infants from studies published over the past 50 years*

<table>
<thead>
<tr>
<th>Age</th>
<th>1933</th>
<th>1964</th>
<th>PGS</th>
<th>NMAA</th>
<th>Adelaide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth</td>
<td>3.74</td>
<td>3.51</td>
<td>3.56</td>
<td>—</td>
<td>3.39</td>
</tr>
<tr>
<td>6 weeks</td>
<td>4.67</td>
<td>5.18</td>
<td>4.81</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3 months</td>
<td>5.91</td>
<td>6.73</td>
<td>5.92</td>
<td>6.31</td>
<td>6.07</td>
</tr>
<tr>
<td>6 months</td>
<td>7.63</td>
<td>8.84</td>
<td>7.85</td>
<td>7.96</td>
<td>7.89</td>
</tr>
<tr>
<td>9 months</td>
<td>8.97</td>
<td>10.71</td>
<td>9.11</td>
<td>9.25</td>
<td>—</td>
</tr>
<tr>
<td>12 months</td>
<td>10.02</td>
<td>11.20</td>
<td>10.01</td>
<td>10.29</td>
<td>10.15</td>
</tr>
<tr>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth</td>
<td>3.62</td>
<td>3.45</td>
<td>3.47</td>
<td>—</td>
<td>3.25</td>
</tr>
<tr>
<td>6 weeks</td>
<td>4.52</td>
<td>4.95</td>
<td>4.60</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3 months</td>
<td>5.73</td>
<td>6.22</td>
<td>5.61</td>
<td>5.71</td>
<td>5.62</td>
</tr>
<tr>
<td>6 months</td>
<td>7.49</td>
<td>8.18</td>
<td>7.44</td>
<td>7.26</td>
<td>7.31</td>
</tr>
<tr>
<td>9 months</td>
<td>8.71</td>
<td>9.40</td>
<td>8.56</td>
<td>8.45</td>
<td>—</td>
</tr>
<tr>
<td>12 months</td>
<td>9.73</td>
<td>10.48</td>
<td>9.50</td>
<td>9.49</td>
<td>9.56</td>
</tr>
</tbody>
</table>

*1933: A retrospective study by F. W. Clements of records from more than 1,000 infants attending Child Health Centres in Sydney (11). 1964: A comparative study from Sydney Child Health Centres, reported by Bell and Lay (15). PGS: This study; The Perth Growth Study. NMAA: A report from the Nursing Mothers' Association of Australia; information obtained by questionnaire (42). Adelaide: A prospective study of growth of infants in South Australia; reported by Boulton (43).
FIG. 2. Comparison of median weights of infants in Australia in the past 60 years. Top, boys; bottom, girls. (From Hitchcock et al., 31.)

"growth standards for infants" (44). The investigators found the most rapid period of growth to be in the first 3 months and that the percentile values for weight, length, and head circumference at birth and 1, 3, 6, 12, and 18 months (the upper limit) were similar to the National Center for Health Statistics (NCHS) values.
Median body weights for boys and girls from birth to 18 months of age were not significantly different from the NCHS values (Fig. 3).

Toronto and Montreal were chosen for this study because of their size (convenient for the study). Sampling was representative of Canadian French- and English-speaking societies; as in our own study, new immigrants were excluded. The survey method was pretested and validated, and a 4-day dietary record method chosen which recorded food consumption in household measures. Commercial brand names and home recipes were recorded. Nutrient intake calculations were done essentially as with the PGS project (45).

Some important points about infant feeding practices emerged from this detailed study of Canadian infants (46). For example, although their daily energy intakes were less than the Canadian recommended daily intakes (RDI) (47), their growth rates were considered normal, suggesting that the RDI was set too high. The authors found low iron intakes from 12 months onward, which they considered to be caused by "low intake of iron-fortified cereals." Their findings suggested that the widespread practice of vitamin supplementation was unnecessary, since the food intakes alone provided sufficient vitamins, e.g., vitamins A and C. Their findings stressed the importance of milk as a major source of energy, protein, fat, and most other nutrients. Milk consumption patterns are clearly different in North America and Australia, as the American practice of feeding skim milk and "2% milk" to infants from 6 months onward (41) is not (yet) prevalent here. Milk was the main source of dietary sodium for the Canadian infants, but by 7 months, table foods became a significant part of the diet. From then on, home-made foods became increasingly important sources of sodium, especially from salt added to

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**FIG. 3.** Median body weights of boys (left) and girls (right) birth to 18 months, from NCHS charts (circles) and the Canadian study by Yeung et al. (44) (crosses).
foods in their preparation or at the table, contributing to their high salt intakes (41).

We have commented previously on how the growth patterns found in our PGS subjects differed from British figures used in comparisons with studies of growth of infants from other countries (48). From 3 to 6 months of age, weight increments were significantly greater in Britain than in Perth. We suggested that this may be due to changes in feeding patterns between the 1950s, when the British figures were derived, and 1980, when the PGS data were obtained. This suggestion would fit with our experience in Australia relating artificial infant feeding and overfeeding in infancy in the 1950s and early 1960s to the perhaps aberrant growth rates observed then, when infantile obesity was increasing (49). This is in comparison with what we are seeing now that breastfeeding is again fashionable, or in the 1930s (11) when breastfeeding was the accepted norm in Australia. As seen below, patterns of growth in the PGS subjects are similar to the NCHS growth curves (50).

**Nutrient Intakes After the First Year**

Important changes were observed in PGS subjects in dietary patterns after 12 months of age. Daily consumption of cow’s milk decreased from a mean of 490 ml at 12 months to 350 ml at 2 years and 300 ml at 3 years. Cheese consumption increased from 7 g/day at 1 year to 12 g/day at 2 to 3 years, but calcium intake was down in comparison to earlier studies. Milk consumption was approximately half that reported in the last comprehensive study of growth of Australian children (51); dietary calcium intake was down by one-third. Fruit juices, fruit juice drinks, cordials, and carbonated drinks seem to have helped displace milk consumption.

At 12 months of age, 15.7% of dietary energy came from protein and 45% from carbohydrate. By 2 years of age, the protein proportion had fallen to 13.8% and carbohydrate rose to 48.1%; this was virtually unchanged at 3 years. These patterns of contribution of dietary energy are similar to those found in older children and family groups in Western Australia (52–54), suggesting that dietary patterns are established as early as 2 or 3 years of age in our community (29).

Dietary intakes of major nutrients in these children are similar at the ages of 1 and 3 years to those of North American children studied in the 1950s (55) and to 3-year-old children studied in Britain from 1967 to 1971 (56,57). They also resemble the findings of Yeung and his colleagues (46) in their longitudinal study of more than 300 normal children from birth to 18 months in Canada.

**Growth in the Second and Third Years of Life**

The growth patterns found in our healthy children in the PGS have been compared with the official Australian growth charts (17) and with the international figures from the NCHS (50). Backward stepwise regression with a second degree polynomial model, including a dummy variable for each set of data, was used to compare percentile values for weight and length against other sets of reference values. F-tests were used to determine the significance of deleting variables from
the regression equation. Variables were included in the equation if the $F$-value exceeded the 95% level (57).

There was no significant difference between the PGS and NCHS data for boys and girls, but the Australian NHMRC median weights are significantly heavier ($p<0.05$) from 6 months of age onward. Figure 4 shows the 50th percentile curves for weights of boys and girls from the PGS, NCHS (50), and NHMRC (17) data. As mentioned earlier, the recent prospective study of Canadian children from 0 to 18 months also fits with the NCHS and PGS patterns of growth (44) (Table 6). These mean body weights are similar to those found in the first year of life in a large, longitudinal growth study of Scandinavian children born between 1955 and 1958, except that both boys and girls tended to be heavier at 12 months of age and beyond (58).

It is not immediately clear why the Australian national reference values (17) are significantly higher from 6 months onward than these other three sets of data from well-documented, recent samples of healthy infants and children in well-nourished populations in industrialized countries. The sample on which the Australian reference values are based was obtained in Sydney in 1970–1972, and the ethnic distribution of the children measured is poorly documented. One reason we took extra care to define the ethnic origins of children in the PGS was the multinational pattern of our present population. Our study showed a strong trend back to breastfeeding; this has also occurred in other states of Australia (34,59–61). The NCHS figures were obtained from infants who were fed breast milk or a low-solute formula designed to simulate breast milk. We have suggested (31) that the return to more natural infant feeding and the decline of bottle feeding based on cow’s milk may have a causal role in the return to patterns of growth in infancy and early childhood that were found in Australia in the 1930s, when breastfeeding prevailed (11). This is supported by the fact that the PGS, NCHS, and NHMRC figures show no differences in length-for-age in the first 3 years, although the NHMRC figures are heavier for age after 6 months. This suggests that the NHMRC sample was relatively overweight from 6 months onward, perhaps because of sampling procedures or infant feeding practices in Sydney at that time, or both.

These results have important implications, at least for Australia, with respect to the use of international sets of reference values for normal growth. One recent local example illustrates this point. We undertook an anthropometric survey of more than 600 Australian aboriginal children up to 30 months of age in an attempt to ascertain their current state of nutrition (62). There was a widespread fall-off in growth commencing in the second half of infancy. As can be seen in Fig. 5, however, the numbers (or proportions) of these subjects that could be considered underweight depend greatly on which set of reference values are used for comparison. For example, many more could be claimed to be "undernourished" using $<80\%$ standard-weight-for-age if the Australian growth charts (17) are used rather than the internationally used NCHS reference values. It may not be valid to compare aboriginal Australians to nonaboriginal Australians for other reasons, e.g., the relatively lighter aboriginal skeleton size compared to a European of comparable
FIG. 4. The 50th percentile curves for boys (top) and girls (bottom) from the PGS (crosses), NCHS (open circles), and NHMRC (solid circles) growth charts.

stature (64). Thus it is probably best to use an independent, internationally accepted reference range of values, such as the NCHS figures.

We should not think of international reference values for growth as "standards" like the gold standard. They should be used, as Waterlow (65) suggests, "like grids
TABLE 6. Median body weights in the NCHS tables, the Perth study, and the Canadian study*

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th></th>
<th>Girls</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NCHS</td>
<td>PGS</td>
<td>Canada</td>
<td>NCHS</td>
<td>PGS</td>
<td>Canada</td>
<td></td>
</tr>
<tr>
<td>Birth</td>
<td>3.27</td>
<td>3.56</td>
<td>3.52</td>
<td>3.23</td>
<td>3.37</td>
<td>3.35</td>
<td></td>
</tr>
<tr>
<td>3 months</td>
<td>5.98</td>
<td>5.8</td>
<td>6.2</td>
<td>5.4</td>
<td>5.55</td>
<td>5.71</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>7.85</td>
<td>7.77</td>
<td>7.88</td>
<td>7.21</td>
<td>7.36</td>
<td>7.39</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>10.15</td>
<td>9.9</td>
<td>9.95</td>
<td>9.53</td>
<td>9.38</td>
<td>9.35</td>
<td></td>
</tr>
<tr>
<td>18 months</td>
<td>11.47</td>
<td>11.47</td>
<td>11.4</td>
<td>10.82</td>
<td>10.8</td>
<td>10.7</td>
<td></td>
</tr>
</tbody>
</table>

*NCHS, National Center for Health Statistics; PGS, Perth Growth Study; Canada, ref. 44.

FIG. 5. Weight-for-age distribution of aboriginal children up to 30 months of age compared with NHMRC (dotted, dashed line), NCHS (solid line), and Kettle's (dashed line) median values (63). (From Gracey et al., ref. 62.)

on a map" as a guide to allow independent comparisons of sets of data from different communities in different parts of the world. They are acceptable in clinical pediatrics because they must be used to show changes in an individual's pattern of somatic growth; minor changes in median values and percentile distributions are unimportant. We should also recognize that adoption of international reference
values does not imply that these are "goals" or "ideals"; they are simply independent reference points which allow objective comparisons of different groups of children, wherever they are. This is not widely appreciated, and poorly documented local standards are being established; in some places, double standards are being used. In places where undernutrition is prevalent, it could be argued that using a large cross-sectional sample of local children does that country or community a disservice by bringing down the 50th percentile value and, therefore, the expectations for growth potential in the minds of local health workers. There are few populations whose growth potential is restricted by their genes; African pygmies are one example. Growth potential for other populations responds to environmental circumstances; in most communities where undernutrition is prevalent, undernutrition and infections are the major factors that limit normal growth.

We have publicly cautioned against the development of a new, national growth standard for infants and children in Australia (66). The same arguments apply to similar countries who should adopt the international reference values (67).

ACKNOWLEDGMENTS

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REFERENCES

42. Shade E. Weight gains in breast fed infants. Nursing Mothers' Association of Australia Newsletter, April 3-9, 1980.

DISCUSSION

Dr. Whitehead: Figure 2 is a truly remarkable graph. It illustrates well the value of carrying out anthropometric surveys on a regular basis so that one can determine accurately trends of change. Your data, Dr. Gracey, indicate that there has been a peak in the size of children achieved at different ages. Skinfold thickness measurements carried out in the United Kingdom also indicate that we have gone through a peak. Do you know of any similar data from other countries?

Dr. Gracey: The studies by Taitz in the United Kingdom relate the recent trend to lower weight velocities to the phasing out of unmodified milks and the discouragement of over-
concentrated feeding. Workers in the United States in the 1970s also found differences in weight gains between breastfed and artificially fed babies. I cannot say whether there is now a general reversal of these patterns in the Western world in the 1980s.

**Dr. Anderson:** The peak in England probably was related to the decline in breastfeeding and the change to early feeding of solids during the postwar years. A study in Dudley, Worcestershire (19), in 1972 of a large group of infants in their first year illustrated this growth increase. In the United States, dietary solids were introduced in very early infancy long before, and perhaps they had the growth peak earlier.

**Dr. Barness:** That is correct. The early introduction of solids in the United States began about 1935. This persisted until about 1978 when the Committee on Nutrition of the American Academy of Pediatrics recommended against these practices. The recommendation is that no supplemental foods be introduced before 4 to 6 months.

**Dr. Guesry:** When you take only breastfed babies in group D, do they behave like the babies in group A?

**Dr. Gracey:** Bell and Lay's sample, in 1964 (15), was selected to be representative of the Australian population at that time. From our own study, numbers are too small to assess, statistically, whether breastfed babies in group D behave like group A infants. We now know, from a prospective study of several hundred infants in Western Australia, that breastfeeding has a significant effect on weight gain in the first 12 months. From 0 to 3 months, there was no significant difference in breastfed or bottle-fed infants. After that, however, weight gains were greater in those artificially fed from birth or breastfed for only a short time when compared to those exclusively breastfed for 6 months or partially breastfed for 6 months or longer. [Hitchcock NE, Gracey M, Gilmour AI. The growth of breast fed and artificially fed infants from birth to 12 months. Acta P Scand 1985:74 (in press).]

**Dr. Abdul Kader:** With respect to Fig. 2, for the modality of weight, do you have a similar chart for the head circumference during these years? If so, what does it look like?

**Dr. Gracey:** Head circumferences in our study were not significantly different from our national growth charts. My interpretation of the data is that the children studied in the mid-1960s were relatively overweight, and that the cross-sectional sample taken in 1970–1972 to devise our national growth curves also included a considerable proportion of overweight children.

**Dr. Mata:** I am interested in Fig. 4, which shows the scattering of weight-for-height values of Australian aboriginal children today in comparison with the data of 1966, actually showing that your weight-for-height is improving; in other words, the children have become heavier. I would have expected malnutrition in your children. My impression is that your children are very slender, particularly in the legs, which is thought to be an adaptation to walking in deserts over the last 70,000 years. My question is: do you have in the original paper the same scattered diagrams for height and for weights separately? What do they look like?

**Dr. Gracey:** Yes; they look almost the same, which is the explanation for why you would have thought there was little malnutrition in these children because they are proportionately (i.e., weight-for-length) almost normal.

**Dr. Mata:** What impressed me more about Western Australia was that most women were tall, about 170 cm, and young girls were also very tall and very slender. That may represent a derivation of their good nutritional status, or it may be due to other factors. In Guatemala and Honduras, many people are stunted as adults, but among the aborigines, this is not so; it would be interesting to see if there is an inverse trend among adults. Do adults tend to be shorter today?
Dr. Gracey: You raised several important points. In the Kimberley region, in the tropical northwest of Australia, aboriginal children seem to be mostly short and light up to about 10 to 12 years of age; thereafter, there appears to be a period of catch-up growth. Why is this situation so different from what you see in Latin America? There is, generally, adequate food and money (from social welfare) in aboriginal communities, yet undernutrition is widespread in aboriginal children. On the other hand, there is a recently emerging problem of adult obesity in aborigines, particularly in women. I suspect the high level of environmental contamination in aboriginal communities and the heavy exposure of their children to repeated infectious diseases are important causes of growth retardation.

Dr. Nordio: With respect to the speculations concerning changes of infant growth during time, I do not think that changes within 10 to 20 percentiles are significant in terms of health. Growth and development should always be considered in the ecosystem context to avoid dangerous tunnel vision. In relation to population nutrition and health, the problem is to define valid and simple indicators to establish a risk-threshold for malnutrition, for hyponutrition in the developing countries, and for hyperunbalanced nutrition in the developed ones.

Dr. Gracey: It seems that the cutoff points that we normally use to assess risk are fairly crude.

Dr. Waterlow: Regarding the question of risk, the only studies of which I am aware are those from India (Kielmann AA, Mc'Cord C. Lancet, 1978;1:1247–50) and Bangladesh (Chen LC, Chowdury AKM, Huffman SL. Am J Clin Nutr 1980;33:531–5), in which cutoff points were established where the risk steeply rises. Personally, although I agree with the concept, I do not think that these data are particularly useful because the risk attached to a given height or weight deficit will vary according to the circumstances. It will be one thing in a country like Bangladesh where there is an enormous infectious load, and it will be different in a different country. Death is not the outcome in which we are normally most interested; one would like to have risks of morbidity and of some developmental failure, but these are difficult to establish.

Whether stunting is due to malnutrition or to infection is in a sense irrelevant; in the end, it is either a metabolic or a nutritional process that has gone wrong. There is evidence that the children are much less stunted in communities where they have a high protein diet, such as some of the tribes in Kenya and Northern Nigeria, people living on fish on certain islands, and so on. I do not know whether it is protein, minerals, or calcium but my hypothesis is that there is a nutritional cause for stunting. I cite a study by Fomon et al. (Fomon SJ, Filer LJ, Ziegler EE, Bergmann KE, Bergmann RL. Acta Paediatr Scand 1977;66:17–30), in which the authors fed a group of children dried skimmed milk. The children had a good protein intake and a poor energy intake, but there was absolutely no difference in height growth between those children and another group whose intake was adequate for both protein and energy; they were thin but tall. Your aboriginals, presumably, were living in past times on hunting and mainly on meat, rather than on starchy roots and such staples.

Dr. Gracey: Your comment about being unconcerned whether the cause is nutritional or infectious relates to the mechanisms involved in the eventual outcome. From a public health viewpoint, it is important to determine which mechanism is most important to help establish proper priorities in preventive programs.

Dr. Mata: I am puzzled with Fig. 4 because there must be about 20 to 30 datum points falling below the third to fifth percentile of the NCHS. A graph like that in Central or South America is associated with an infant mortality of about 60 per 1,000 and with 1 to 3% of chronic or severe malnutrition. In your aboriginal communities, however, the infant mortality
is about 24 to 26 per 1,000. The birth rate has dropped tremendously, and primary health care has virtually eradicated polio and measles. My impression is that infection is not as common among Western Australian aborigines. Your communities consist of very small tribes, separated from one another by hundreds of kilometers, with limited possibilities for spread of infection.

Dr. Gracey: In the late 1960s and early 1970s, the incidence of infectious diseases in aboriginal children was very high, similar to the situation in developing countries such as India, Indonesia, and Bangladesh. This situation has changed in a dramatic way in the past 10 years. For example, the hospital admission rate for aboriginal infants for gastroenteritis in the Kimberley region in 1971 was 393%; by 1980, this rate had fallen to 24%. On a statewide basis, the annual rate, in Western Australia, declined from 171% per annum in 1971 to 36% in 1980. This is important in our consideration of risk factors. The improvements achieved in Western Australia are attributable to several interrelated factors, such as general standards of living, housing, hygiene, and the provision of comprehensive, community-based, preventive health programs.

Dr. Whitehead: We must consider the functional interpretation of growth achievements. If it is true that height and weight attainments of babies in the future are going to be less than they were during the bottle-feeding peak of the 1960s, people are bound to ask whether or not this matters in a functional sense. This has long been a problem for the developing world, where there have been a number of attempts to equate weight-for-age with, for example, immunological status. As far as the Western world is concerned, neurological and neuromotor development might be more important. Would the pediatricians here like to tell us of the functional parameters they would like to see measured along with the anthropometric ones?

Dr. Falkner: You have, as usual, picked out an important area where there are few hard data. The multidisciplinary teams engaged in longitudinal studies rarely relate their data from one discipline to another, for example, mental-behavioral development patterns related to neuromuscular development.

Dr. Waterlow: Cravioto et al. (Cravioto J, DeLicardie ER, Birch HG. Nutrition, growth and neurointegrative development: an experimental and ecologic study. Paediatrics 1966;38:319–72) have performed a variety of tests of neurosensory and neuromotor development and related them to deficits in height. The results show clearly that the stunted child is disadvantaged developmentally. The causal nexus, of course, is by no means clear.

Dr. Falkner: I was actually referring to the "normal child." There are few hard data on the mental development of normal children, in longitudinal studies, related to their somatic development. Such data are needed as a starting point.

Dr. Butte: We seem to have missed one important observation made by Dr. Whitehead: the exclusively breastfed infants tended to stay around the 25th percentile throughout the first year of life, even after complementary foods were introduced. Before we come to the conclusion that this represents normal growth, we must determine whether these mothers were imposing food restriction on their infants and whether the development of these infants was compromised in any way. These are the type of growth curves we associate with infants reared under less favorable conditions.

Dr. Whitehead: That is correct. Also, Dr. Waterlow was concerned that we should not automatically assume that trends within the professional classes in countries such as the United Kingdom inevitably set the ideal for everyone else.

It is going to be difficult indeed to produce any convincing relationship between different types of anthropometric growth and the functional capacities with which they may be
associated. There may be a range of weights and heights for each individual which would be compatible with his health and well-being in the broadest sense.

Dr. Barness: We may be overemploying nutrition in child development.

Dr. Anderson: Dr. Whitehead and others have been discussing small variations in growth in the first 2 years of life and a recent slight falling off in rate; are they making too much of this? Is it not just a reversion to a growth pattern of several decades ago because of a change back to earlier feeding patterns? Is it also just a short-term variation? The Dudley study I mentioned previously showed that those overweight at 1 year were normal at 5 years. The comprehensive Child Development Study over 21 years in England should contain material of interest to nutritionists in this regard.