Early Excess Weight Gain of Children in the Pima Indian Population

Robert S. Lindsay, MB, PhD*; Valerie Cook, PhD, CPNP‡; Robert L. Hanson, MD, MPH*; Arline D. Salbe, PhD*; Antonio Tataranni, MD*; and William C. Knowler, MD, DrPH*

ABSTRACT. Objective. To determine the period of childhood in which weight relative to height increases in Pima Indian children and young adults in comparison with the general US population.

Methods. Heights and weights of children in the Pima Indian population were derived from either clinical examinations conducted by the Department of Public Health Nursing (from 1–48 months of age), or from examinations in the National Institutes of Health longitudinal survey of health in the Pima population (for birth and ages 5–20 years), and compared with standards for the US population recently published by the National Center for Health Statistics.

Results. Weight relative to height (weight-for-length in children aged <24 months, body mass index at ages ≥2 years) was significantly higher in Pima children at all ages examined after the first month of life. Compared with reference values, the most dramatic increases in weight relative to height occurred in 2 stages of childhood: mean z scores of weight-for-length increased between 1 month (mean ± SEM: males: −0.2 ± 0.19; females: −0.02 ± 0.14) and 6 months (males: 0.8 ± 0.04; females: 0.7 ± 0.04) of age; mean z scores for body mass index increased gradually between 2 years (males: 0.4 ± 0.06; females: 0.4 ± 0.08) and 11 years (males: 1.4 ± 0.08; females: 1.4 ± 0.08) and remained stable thereafter.

Conclusion. Excessive weight gain occurs early in the Pima population with changes relative to reference values most marked in the first 6 months of life and between 2 and 11 years. Interventions toward primary prevention of obesity may need to be targeted at children and adolescents rather than adults in this population. The Pima Indians of Arizona have a particularly high prevalence of obesity in both adults and children and suffer from a variety of secondary health consequences—most notably high rates of type 2 diabetes.3

Excess weight gain in childhood is important for a number of reasons. First, obesity is increasingly recognized in pediatric populations, with attendant concerns regarding immediate and future effects on health.4 In the Pima population, both obesity and type 2 diabetes are recognized as important health problems in childhood.5,6 Second, weight gain in childhood may be an important antecedent of obesity in adult life. Body mass index (BMI) tracks through childhood, so that childhood BMI predicts adult obesity.7 The disappointing results of attempts to treat obesity in adults and children have led to suggestions that health care interventions might most profitably be directed at prevention rather than treatment of obesity.1 In many populations, including the Pima Indians, prevention of obesity in adults may therefore chiefly involve interventions conducted in childhood.8

Extensive data from a longitudinal survey of health in the Pima population conducted by the National Institutes of Health (NIH) have recorded increases in obesity at ages over 5 years, whereas birth weight appeared similar to that of the general population.7 Our aim was to extend these observations with addition of heights and weights in children under the age of 5 years to describe the pattern of weight gain from birth to age 20 compared with recently published standards for the United States,10 and to examine whether gain of adiposity occurred early in life in the Pima population. It is hoped that knowledge of the stage of childhood at which the Pima population begins to differ substantially from the background US population in terms of weight-relative-to-height may guide future interventions aimed at primary prevention of obesity.

METHODS

Examinations at Age 1 to 48 Months Old

Data on weight and growth at ages below 5 years are included with the help and permission of Gila River Health Care Corporation from well-child examinations in the Pima community between January 1990 and June 2000. Children are routinely scheduled to have measurements of weight and height at 1, 2, 4, 6, 9, 12, 18, 21, 24, 36, and 48 months. Children were assessed in a community-based, well-child clinic by trained staff using a measuring board for length in those <2 years old and a stadiometer or wall tape for height determinations in those ≥2 years old. Weight was measured using electronic scales with participants undressed apart from a dry diaper or underpants.

Data from 8479 examinations of 2200 children were obtained...
(for examinations at 3 and 4 years, only those made within 3 months of child’s birthday were considered). Examinations (N = 289) were excluded where there were either logical inconsistencies (eg, of dates of birth and examination) or very discrepant values of height or weight (>5 standard deviation [SD] from the age-adjusted and sex-adjusted median for the Pima population) that could not be corrected from paper records. Finally, where a single individual had >1 examination within an age group, only the examination closest to the central age of the age group was included to maintain statistical independence of observations within each age group. Results from a final total of 7878 examinations from 2117 children (median: 4 examinations per child; range: 1–8 examinations) are presented (Table 1).

Examinations at Ages Over 5 Years and at Birth

Data in children aged over 5 years are derived from participants in the NIH survey of diabetes in the Gila River Indian Community.3,6 Informed consent was obtained from participants (if age ≥18 years and emancipated minors) or their parents (for those aged <18 years, in which case the assent of the child was also obtained) and ethical approval was received from both the NIH and the Gila River Indian Community. All members of the community older than 5 years were invited to a biennial examination with measurement of height and weight, with the participant wearing light clothing and no shoes. Glucose tolerance was assessed by a 75-g oral glucose tolerance test in fasting participants. Diabetes was diagnosed using World Health Organization 1985 criteria.11 To allow comparison with data from well-child examinations, analyses of data from NIH examinations were restricted to the same time period in which well-child data were collected (1990–2000), leading to a final total of 4140 examinations from 2546 individuals (median: 1 examination per child; range: 1–6 examinations) examined at ages 5 to 20 years (Table 1). The percentages of children diagnosed with type 2 diabetes at or before examination is shown for each age group in Table 1.

Birth weights and duration of gestation were derived either from the birth certificate or from review of hospital records at each biennial visit in participants in the NIH study. Data on birth weight were included if gestation at delivery was recorded as between 38 and 42 weeks (244 males, 289 females). Analysis of length at birth has not been included as most data had been recorded in inches without fraction or decimal point, and this was deemed insufficiently precise to allow comparison to reference values.

Comparison With Reference Values and Other Statistical Methods

Weight (from birth to 20 years), stature (from 1 month to 20 years), weight-for-length (from 2 years to 20 years), and BMI (from 2–20 years) were compared with standards published by the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics (NCHS).10 In the NCHS data, parameter values for median, SD, and power in Box-Cox transformation are provided in 1-month intervals from birth to 20 years (for height and weight), from 2 years to 20 years (for BMI), and from birth to 36 months (for weight-for-recumbent length).10 This allows the extent to which each individual deviates from the reference value to be calculated in terms of a normalized score (z score). If a population has the same distribution of values as the reference population, then the mean z score will be 0 with SD of 1. z Scores for Pima children were calculated using parameters for the month closest to the age of the child at examination as described in Kuczmarski et al.10 To allow calculation of mean and standard error of z scores for different ages in the Pima population, z scores were grouped by age (birth, 1, 2, 4, 6, 9, 12, 15, 18, 21, 24, 36, and 48 months for children aged under 5 years; 1 year blocks from 5 years to 20 years). Thus, data presented for “age 6” represents z scores of children examined between 5.5 and 6.5 years. The significance of deviation of z scores from reference values was assessed by Student t test, against a null hypothesis of mean z score = 0 (as would be expected if there were no difference of the Pima population from reference values). To adjust for multiple testing (58 potential examinations for males and females between birth and 20 years), Bonferroni corrected P values resulting from these t tests are presented.

Influences of gender on z scores were examined by entering z scores for weight, stature, BMI, or weight-for-length into a mixed regression model. To allow use of all available data, including multiple (nonindependent) measures from individuals, the influence of each individual on z score was modeled as a random effect, whereas the influence of gender and age at examination (linear and quadratic terms) were examined as fixed effects.

Comparison of the correlation of BMI and stature (length in children aged <24 months, height in those aged ≥24 months) was achieved by means of Pearson correlation after adjustment for age and stratified for age group and gender.

RESULTS

At birth, Pima children were slightly heavier than reference values, a difference that was only significant in males (mean z score ± SEM: males: 0.2 ± 0.06, Bonferroni corrected P = .01; females: 0.1 ± 0.06, P = .9; Fig 1A). By contrast, at 1 month Pima children were on average lighter and shorter (Fig 1B), although these differences did not reach statistical significance, and weight-for-length was not different from reference values (Fig 1C). Between 1 month and 6 months, weight-for-length in Pima children showed increasingly large deviations from reference values, such that by 6 months z scores for the average

### TABLE 1. Numbers of Examinations in Each Age Group

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Male</th>
<th>Female</th>
<th>Age (Months)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>244</td>
<td>289</td>
<td>5</td>
<td>79</td>
<td>68</td>
</tr>
<tr>
<td>1</td>
<td>54</td>
<td>78</td>
<td>6</td>
<td>118</td>
<td>147</td>
</tr>
<tr>
<td>2</td>
<td>445</td>
<td>444</td>
<td>7</td>
<td>134</td>
<td>143</td>
</tr>
<tr>
<td>4</td>
<td>473</td>
<td>477</td>
<td>8</td>
<td>157</td>
<td>165</td>
</tr>
<tr>
<td>6</td>
<td>537</td>
<td>589</td>
<td>9</td>
<td>173</td>
<td>183</td>
</tr>
<tr>
<td>9</td>
<td>114</td>
<td>119</td>
<td>10</td>
<td>194</td>
<td>200</td>
</tr>
<tr>
<td>12</td>
<td>503</td>
<td>518</td>
<td>11</td>
<td>171</td>
<td>225</td>
</tr>
<tr>
<td>15</td>
<td>188</td>
<td>198</td>
<td>12</td>
<td>226</td>
<td>236</td>
</tr>
<tr>
<td>18</td>
<td>458</td>
<td>511</td>
<td>13</td>
<td>217</td>
<td>219</td>
</tr>
<tr>
<td>21</td>
<td>68</td>
<td>50</td>
<td>14</td>
<td>196</td>
<td>231</td>
</tr>
<tr>
<td>24</td>
<td>169</td>
<td>172</td>
<td>15</td>
<td>189</td>
<td>181</td>
</tr>
<tr>
<td>36</td>
<td>428</td>
<td>471</td>
<td>16</td>
<td>162</td>
<td>174</td>
</tr>
<tr>
<td>48</td>
<td>404</td>
<td>410</td>
<td>17</td>
<td>106</td>
<td>174</td>
</tr>
<tr>
<td>5 years</td>
<td>124</td>
<td>140</td>
<td>18</td>
<td>108</td>
<td>175</td>
</tr>
<tr>
<td>8 years</td>
<td>88</td>
<td>111</td>
<td>19</td>
<td>88</td>
<td>151</td>
</tr>
<tr>
<td>10 years</td>
<td>54</td>
<td>59</td>
<td>20</td>
<td>54</td>
<td>77</td>
</tr>
</tbody>
</table>

A total of 7878 examinations at 1 to 48 months (49% male) and 5121 examinations at ages ≥5 years (46% male) were included. For children aged 5 and above, numbers in parentheses indicate the percentage with diabetes diagnosed before or at that examination.
Pima child were 0.7 to 0.8 (mean z score: males: 0.8 ± 0.06, Bonferroni corrected $P < .0001$; females: 0.7 ± 0.06, $P < .0001$; Fig 1C). Weight-for-length relative to reference values did not increase thereafter, with mean z scores remaining in the range of 0.6 to 0.9 until examinations at age 2, and with a similar difference from reference values in males and females (effect of gender in model, $P = .3$). In the first 2 years of life, Pima children were generally shorter than reference values (Fig 1B), with males showing a greater difference from expected values than females ($P < .0001$). Females remained significantly shorter than expected up to and including examination at 12 months of age, whereas males remained significantly shorter to 21 months (Fig 1B).

After the age of 2 years, Pima children were significantly heavier and had higher BMI than reference values ($P < .0001$). The mean z score for BMI increased from 0.4 at age 2 (males: 0.4 ± 0.09; females: 0.4 ± 0.08) to 1.4 at age 11 (males and females having identical values of 1.4 ± 0.07). At ages above 11, BMI in Pima children remained higher than reference values with mean $Z$ scores between 1.3 and 1.5 in males and 1.3 and 1.6 in females. This represents mean values >90th percentile compared with the reference population in both sexes. $Z$ Scores for females tended to be higher than in males, although not statistically significantly so (including all data from age 2–20; $P$ for effect of gender = 0.2). Median values of BMI by age group are presented in Fig 2. Median BMI in the Pimas was approximately equivalent to the reference population 75th percentile at ages 3 and 4 years in both males and females (Fig 2B). The median BMI in Pimas rose at subsequent ages to around the 97th percentile of the reference population at age 10 in males and age 11 in females and remained at that level (Fig 2A).

Height in Pima children showed a quite different pattern from BMI (Fig 1B). Linear growth was accelerated in the middle years of childhood: between ages 4 and 14, both males and females were taller than reference values, with the maximum deviation from reference standards occurring at age 10 in females and 12 in males (Fig 1B). By contrast, from age 18 in females and 17 in males average height was shorter than reference values (Bonferroni adjusted $P$ value < .05). This final deviation from reference values was relatively small (−0.3 to −0.5 SD in males and −0.3 to −0.4 SD in females at ages 17–20) representing a difference of

---

**Fig 1.** $Z$ Scores of mean weight, stature, BMI, and weight-for-length by age in Pima children and adolescents. $Z$ Scores for (A) weight, (B) stature (length in children aged under 2 years and height for children ≥2 years), and (C) weight-for-length (in children <2 years) and BMI (in children ≥ 2 years). Mean $z$ score is presented for each age group either + or −SEM for each sex.
around 1 to 2 cm in females and 2 to 3 cm in males from reference median values. Height showed a positive correlation with BMI through most of childhood (Bonferroni adjusted $P < .05$ in males at ages from 4–16 inclusive and in females at ages from 4–13 inclusive and age 16; Fig 3).

**DISCUSSION**

Treatment of obesity in adults and children is generally minimally effective, and this has led to calls for a concentration of health care resources on the primary prevention of excess weight gain. Our results suggest that, on a population basis, weight relative to height of Pima children begins to deviate early in life from levels typical for other children in the United States. In particular, values for the average Pima child cross-referenced centiles in 2 periods of childhood, between the first and sixth months of life and subsequently between age 2 and 11 years. After 11 years, BMI increases but at a rate similar to the reference population, without crossing of centile lines. It is important to note that these data are primarily cross-sectional—we cannot be certain that subjects followed longitudinally would follow the same pattern.

Fig 2. Median body mass index in Pima children and adolescents compared with CDC reference values. Lines represent 3rd, 10th, 25th, 50th, 75th, 90th, and 97th centiles from reference values derived from the US population. Filled circles represent median BMI for males or females in the Pima population. Data are presented for (A) ages 2 to 20 and (B) ages 2 to 4.

Fig 3. Correlation of stature and BMI in Pima children and adolescents. Pearson $r$ values for the correlation of stature (height at ages ≥2 years, length at ages <2 years) and BMI (kg/m$^2$) after adjustment for age. Bonferroni adjusted $P < .05$ (nominal $P$ value for single test <.0009) for values for males between the ages of 4 and 16 inclusive and females from ages 4 to 13 inclusive and also 16 years of age.

There are a number of potential weaknesses of our study. The measures we rely on for assessment of adiposity (BMI at ages over 2 years and weight-for-
length in younger children) are indirect measures of adiposity and, therefore, potentially misleading. BMI correlates well with direct measures of adiposity, such as underwater weighting and body composition by dual energy radiograph absorptiometry, in Pima adults and children\(^{3,22}\) and in other populations,\(^{13,14}\) although this relationship is influenced by factors including age,\(^{13,14}\) gender,\(^{15}\) and sexual maturation.\(^{16}\) In Pima children, studies relating BMI to percentage fat by dual energy radiography absorptiometry show correlation coefficients ranging from 0.83 to 0.94, but are limited to children over 5 years.\(^{12}\)

It is important, therefore, to be cautious about interpreting increased BMI or weight-for-length at younger ages as an indicator of increased adiposity; this is highly likely to be the case, but would await definitive studies with direct measures.

Selection of the reference population might also influence our findings. The NCHS reference values are drawn primarily from 5 population surveys conducted in the United States between 1963 and 1994, namely National Health Examinations Survey Cycles II and III and National Health and Nutrition Examination Survey (NHANES) I, II, and III\(^{10}\) with sampling designed to represent the ethnic background of the US population. This allows us to compare data from Pima children to expected patterns for the general US population, but does not allow delineation of whether those difference are determined by underlying genetic or environmental factors. In addition, part of the difference between Pima children and the reference population may relate to secular rather than ethnic differences. For children aged \(\geq 6\) years data from the last of the national surveys was excluded (NHANES III), specifically to avoid an upward shift in weight and BMI curves secondary to secular increases in these variables in the United States population.\(^{10}\) We are therefore comparing Pima children examined from 1990–2000 with a reference population drawn, on average, from earlier examinations. This may account for a modest part of the differences we detect. Nevertheless, because of the broad clinical use of the CDC standards, they are the most appropriate reference for the present purpose.

Despite the caveats noted above, it seems likely that in the Pima population excess accumulation of fat begins early. Apart from studies of birth weight, this is the first publication of weight, height, and adiposity in Pima children before the age of 5 years. It would seem from our data that Pima children on average accumulate weight relative to height in a similar fashion to the reference population apart from 2 periods of life: at ages 1 to 6 months (weight-for-length) and 2 years to 11 years (BMI). For the reasons discussed above, it seems likely—at least from age 5 to 11 years—that this represents a true accumulation of adiposity compared with the reference population. It is more difficult to be certain that the increase in weight-for-length observed between 1 and 6 months represents an increase in adiposity.

There are number of potential explanations for the increase in weight-for-length between the first and sixth months of life. First, there may be an underlying genetic difference in growth in this period. Second, the difference may relate to mode of feeding. Breastfed infants grow differently from bottlefed infants, gaining less weight and weight-for-length in the first year of life.\(^{17}\) In children examined as part of the third NHANES survey, these differences were most marked between 8 and 11 months of age with a difference in \(z\) scores for weight for length of 0.25 between breastfed and bottlefed groups.\(^{17}\) The CDC references against which we have compared Pima children incorporate growth data from 3 national surveys within which around half of infants are reported to have ever been breastfed and one third breastfed for 3 months or more.\(^{10}\) We do not know how many of the children examined in this report were breastfed: a previous survey in the Pima community suggested that for children born between 1973 and 1977 around 45% of children had ever been breastfed, but only 4% had been exclusively breastfed.\(^{18}\) It is quite possible that some of the excess weight gain we have observed relates to a higher prevalence of bottlefeeding than the reference population. This is an important possibility because the mode of feeding may influence health in the longer term: breastfeeding is associated with a lower risk of later type 2 diabetes in the Pima population\(^{19}\) and has been associated with lower risk of obesity in white children at 5 to 6 years.\(^{20}\)

It should also be noted that the difference from the reference population that we observe in weight-for-length at 6 months are greater than those observed previously as an effect of bottle versus breastfeeding; this raises the possibility that other factors may be acting. Importantly, evidence for a genetic contribution to adiposity, for which there is strong evidence in later life,\(^{21}\) is very weak for the first 2 years of life.\(^{22}\) Body weight in this period bears little relationship to the presence of parental obesity, with low values of heritability until the age of 3.\(^{22}\) In addition obesity (defined as BMI >85th centile) in the first 2 years is not a significant predictor of obesity in early adulthood.\(^{7}\) These studies suggest that the gain in weight-for-length that we have observed between 1 and 6 months of age is less likely to be mediated by genetic factors and may not be important in the long-term prediction of obesity.

By contrast, the gain in BMI between the second and eleventh years clearly represents an increase in adiposity and is likely to be relevant in development of adult obesity. Understanding risk factors for, and designing effective interventions to prevent, gain of adiposity in this period may be of particular importance. Detailed examination of metabolic risk factors in 5-year-old Pima children indicate that not only does adiposity track between ages 5 and 10 but that factors such as low levels of fat oxidation are associated with gain of adiposity in Pima children, although overall the effect is modest.\(^{23}\)

Pima children seem to have a profoundly different pattern of linear growth than the reference population. Our data suggest an acceleration of growth of height in the middle years of childhood and eventual slightly shorter stature than the reference population. In part, this may reflect genetic differences be-
between Pimas and the reference population. It is also likely that excess gain of adiposity is acting. Obesity is associated with an acceleration of linear growth in childhood and earlier sexual maturation. The pattern of growth is changed, with an increase in growth velocity before puberty and diminished growth spurt during puberty. This is consistent with the pattern we observe in Pima children. Importantly, as the data we present represents means for the population, with relatively few repeated examinations in individual children, we are unable to calculate growth velocities. We do, however, detect strong positive correlations between height and BMI in the middle years of childhood (ages 4–13 in females and 4–16 in males). In adults, BMI developed as a means of adjusting weight for the effects of height to derive an index of adiposity. As there is little relationship of height to adiposity in the adult population this means that, in turn, there is little or no correlation of height to BMI. By contrast, in children, a positive relationship of height and BMI has been previously observed and, importantly, a positive relationship of height to direct measures of adiposity. This suggests that taller children are fatter on average—a finding that is consistent with our observations and the hypothesis that the differences in height we observe are secondary to obesity, although alternative explanations—that another factor influences both development of obesity and linear growth independently—cannot be excluded.

CONCLUSION

We documented increases in BMI and weight-for-length occurring early in childhood in the Pima community. In particular, we identified 2 periods in childhood, between 1 and 6 months of age and from 2 to 11 years of age, when weight is gained at a greater rate than the reference population. If effective obesity prevention interventions are developed, they may have maximum effect when directed at children.

ACKNOWLEDGMENTS

We thank the members of the Gila River Indian Community for their continued support and participation and the Gila River Health Care Corporation for its help and advice. We would like to acknowledge the staff of the Diabetes and Arthritis Epidemiology Section of the National Institute of Diabetes and Digestive and Kidney Diseases, NIH, Phoenix, and the Department of Public Health Nursing, Gila River Indian Community, Sacaton, Arizona, for carrying out the clinical measurements included in this study. We thank Dave Pettitt for helpful comments in the preparation of this manuscript.

REFERENCES

Early Excess Weight Gain of Children in the Pima Indian Population
Robert S. Lindsay, Valerie Cook, Robert L. Hanson, Arline D. Salbe, Antonio Tataranni and William C. Knowler
Pediatrics 2002;109;e33
DOI: 10.1542/peds.109.2.e33

Updated Information & Services
including high resolution figures, can be found at:
http://pediatrics.aappublications.org/content/109/2/e33

References
This article cites 24 articles, 8 of which you can access for free at:
http://pediatrics.aappublications.org/content/109/2/e33#BIBL

Subspecialty Collections
This article, along with others on similar topics, appears in the following collection(s):
Developmental/Behavioral Pediatrics
http://www.aappublications.org/cgi/collection/development:behavioral_issues_sub

Obesity
http://www.aappublications.org/cgi/collection/obesity_new_sub

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
http://www.aappublications.org/site/misc/Permissions.xhtml

Reprints
Information about ordering reprints can be found online:
http://www.aappublications.org/site/misc/reprints.xhtml
Early Excess Weight Gain of Children in the Pima Indian Population
Robert S. Lindsay, Valerie Cook, Robert L. Hanson, Arline D. Salbe, Antonio Tataranni and William C. Knowler

*Pediatrics* 2002;109:e33
DOI: 10.1542/peds.109.2.e33

The online version of this article, along with updated information and services, is located on the World Wide Web at:

[http://pediatrics.aappublications.org/content/109/2/e33](http://pediatrics.aappublications.org/content/109/2/e33)