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The contribution of feeding mode to obesogenic growth trajectories in American Samoan infants

Nicola L Hawley^{1,2}, William Johnson³, Ofeira Nu'usolia⁴, and Stephen T McGarvey¹

¹International Health Institute, Department of Epidemiology, Brown University, USA

²Weight Control and Diabetes Research Center, The Miriam Hospital, Providence, USA

³Division of Epidemiology & Community Health, School of Public Health, University of Minnesota, USA

⁴Tafuna Clinic, American Samoa Community Health Centers, Department of Health. American Samoa Government, American Samoa

Abstract

Background—Samoans are recognized for their particularly high body mass index and prevalent adult obesity but infants are understudied.

Objective—To examine the prevalence of overweight and obesity and determine the contribution of feeding mode to obesogenic growth trajectories in American Samoan infants.

Methods—Data were extracted from the well baby records of 795 (n=417 male) Samoan infants aged 0-15 months. Mixed-effects growth models were used to produce individual weight and length curves. Further mixed-effects models were fitted with feeding mode (breastfed, formula- or mixed-fed) as a single observation at age four (± 2) months. Weight and length values were converted to Z-scores according to the CDC 2000 reference.

Results—At 15 months, 23.3% of boys and 16.7% of girls were obese (weight-for-length > 95th percentile). Feeding mode had a significant effect on weight and length trajectories. Formula-fed infants gained weight and length faster than breastfed infants. Formula-fed boys were significantly more likely to be obese at 15 months (38.6%) than breastfed boys (23.4%), $\chi^2=8.4$, $P<0.01$, odds ratio=2.05, 95% CI [1.04, 4.05].

Conclusion—Obesity in American Samoans is not confined to adults. Obesity prevention efforts should be targeted at early life and promotion of breastfeeding may be a suitable intervention target.

Keywords

Obesity; American Samoa; Breastfeeding

Background

The global prevalence of obesity and the burden of associated chronic non-communicable diseases (NCDs) are continuing to rise. Since the 1970's, Samoans have been recognized for their particularly high body mass index (BMI) and prevalent obesity¹⁻⁵. The most recent

Corresponding Author: Nicola L Hawley Weight Control and Diabetes Research Center 196 Richmond Street Providence, RI 02903 USA N.Hawley@brown.edu **Telephone:** 401-793-8931.

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survey undertaken in American Samoa, the geographic focus of this report, in 2002 found 59% of adult males (aged 18-74 years) and 71% of adult females to be obese according to Polynesian standards (BMI ≥ 32 kg/m²)⁶. These levels of obesity are representative of Oceania as a whole, with this region having the greatest mean BMI worldwide and a rate of increase in BMI more than three times the world average over the past 30 years⁷.

There is particular focus on infancy (i.e., 0-3 years) as a critical period in obesity development. Excess adiposity early in life has both immediate and long term health consequences. In the short term, obese children exhibit pulmonary, gastroenterological, orthopedic and endocrine complications⁸⁻¹². Persistence of these complications into adolescence and adulthood is common, and the long term consequences for morbidity and mortality are well recognized^{13,14}. It is important to investigate the growth of Samoan infants to determine the age at which obesogenic growth trajectories are established and thus identify the ideal age at which obesity prevention programs should be targeted.

Identifying potential intervention targets to stem the obesity epidemic has become a global public health priority. Differences in the growth of breast- and formula-fed infants are well recognized¹⁵⁻¹⁷ and for this reason it has been hypothesized that breastfeeding may be protective against obesity¹⁸⁻²⁰. The generalizability of these findings to populations not of European origin has recently been questioned²¹. In Samoans, initiation of breastfeeding is almost universal but the duration of exclusive breastfeeding is short (around two months)²². Evidence that breastfeeding attenuates the risk of obesity in Samoans would support the targeting of this modifiable behavior in early obesity prevention efforts.

This paper has three aims: (1) to use longitudinal data to assess the growth of Samoan infants relative to the CDC 2000 reference, the clinical tool most commonly used for routine growth assessment in American Samoa; (2) to describe the prevalence of overweight and obesity during infancy; and (3) to examine the impact of infant feeding mode on early life growth trajectories and the risk of overweight and obesity.

Methods

Sample

Data for these analyses were extracted during a review of medical records in American Samoa in June 2008. The records of 1053 singleton infants born between 2001 and 2008 from mothers residing in the catchment area served by the Tafuna Clinic were available for review. The Tafuna Clinic is one of the American Samoa Community Health Centers serving a population of approximately 20,858 residing in Tualauata County, American Samoa²³. All of the infants were referred to the clinic for well baby follow up visits after delivery at the Lyndon B Johnson (LBJ) Tropical Medical Center in Pago Pago, the capital of American Samoa, where the majority of deliveries in American Samoa (97% of ~1300 per year) occur. Infants were included in the study sample if they were of Samoan ethnicity (based on maternal report), a singleton, term birth (37-42 weeks), had measurements of weight and length at birth and at least one postnatal recording of weight and length. The sample comprised 795 (n=417 male) infants.

Data

Weight and length at birth were extracted from delivery room records at LBJ. Infant gender, gestational age at birth (estimated from maternal report of the last menstrual period), and maternal characteristics were extracted from antenatal clinic records also located at LBJ. Subsequent infant growth data (weight and length) and status quo reports of infant feeding at each well baby visit were obtained from Tafuna clinic records. All procedures were

approved by the appropriate institutional review boards at Brown University and the American Samoa Department of Health.

Modeling weight and length growth curves

Mixed effects growth models stratified by sex were applied to weight and length data collected from 0.07-1.3 years of age to produce individual curves using *xtmixed* in Stata IC10 (College Station, Texas). Birth data were not included in the models to improve convergence. In total, 2883 weight measurements, with an average of 3.6 per infant (range 1 to 10) over an average of 0.67 years (range 0 [for those with only one assessment] to 1.26 years), and 2857 length measurements, with an average of 3.6 per infant (range 1 to 9) over an average of 0.67 years (range 0 to 1.26 years), were modeled. The Berkey-Reed 1st order function²⁴ provided a better fit for both the weight and length data than other tested structural (e.g., Count) and non-structural models (e.g., polynomials and fractional polynomials). Using the estimates of the fixed and random effects, individual estimates of weight and length at each month of age between one and 15 months were calculated.

Observed birth weight and length, and the monthly estimated weight and length values from the mixed effects models, were converted to Z-scores according to the CDC 2000 reference²⁵. Rapid and extremely rapid infant weight gain were defined as a difference between Z-scores at time T+1 and Z-scores at time T of more than +0.67 Z-scores and +1.34 Z-scores. This is equivalent to crossing upward through one or two major centile bands respectively (i.e. from the 50th to the 75th or the 50th to the 90th centile). To account for regression to the mean, these weight gain variables were calculated as the residuals from sex specific linear regression of Z-scores at time T+1 on Z-scores at time T. The percentage of infants classified as overweight (i.e., weight-for-length > +1.04 Z-scores = 85th centile) and obese (weight-for-length > +1.64 Z-scores = 95th centile) was calculated at each month of age. The prevalence of overweight, obesity, and rapid growth was compared between sexes using chi-squared tests. Prevalence of obesity was also estimated using the World Health Organization (WHO) growth standard²⁶ and results are presented in table three for comparison with the CDC estimates.

Infant feeding effects on growth curves

Further mixed effects models were fitted to investigate the effects of infant feeding on the mean growth curves. Each observation of feeding was coded as: breastfed (exclusive as well as supplemented with water), formula-fed (including those supplemented with water), mixed-fed which included infants fed a combination of breast milk and formula, or fed solid foods. In the first set of models, every observation of infant feeding was included. Feeding was added as a time dependent variable by fitting it as a main effect and as an interaction with age allowing each mean curve its own intercept and gradient. Because, however, feeding mode was fitted in this way (i.e., a child could be breastfed at one age, bottle fed at another) it was not possible to calculate individual monthly values and convert to Z-scores. A second set of models were, therefore, fitted using a single observation of infant feeding at age four months, plus or minus two months. Four months of age was chosen following WHO recommendations²⁷. If an infant did not have feeding data at four months, feeding mode at the closest point in time (within two months) was included. The effects of feeding on growth were similar whether feeding was included as a time dependent variable or as a single observation. The mean weight and length curves based on the single observation at age four months are presented here.

The sample for the feeding analysis was restricted to 642 (n=336 male) infants with an infant feeding response at age four months, plus or minus two months. There were a further 27 cases where solid food was reported as the feeding mode in this age range. The

observations of weight and length in these infants were, however, too few to model as an individual group and they were excluded. Based on these infant feeding models, individual estimates of weight and length at each month of age between one and 15 months were calculated. Differences in weight and length at each month according to feeding status were compared using ANOVA with Bonferroni *post hoc* measures. Z-scores were also calculated, as were overweight, obesity, and weight gain variables. These variables were used to investigate the effects of infant feeding on obesity traits.

Results

Sample Characteristics

Mothers were an average 28 years of age at the birth of these infants, were largely married and multiparous. The majority of deliveries (84.5%) were normal spontaneous vaginal deliveries occurring at or after 40 weeks of gestation. Macrosomia was present in 20.6% of the infants, with the majority of these classified as grade I macrosomia (4000-4449g; 16.6% of all births).

Growth versus the CDC 2000 reference

Both sexes displayed a similar and striking pattern of growth during infancy (fig. 1 and 2). While the length-for-age Z scores of these infants rose steadily throughout infancy, weight gain in early infancy occurred far more rapidly in these Samoan infants than in the CDC reference population resulting in a marked upward crossing of CDC weight-for-length centiles between birth and four months. At birth, mean weight-for-length in both sexes was close to the CDC median (-0.13 and 0.00 Z scores in boys and girls respectively). By four months mean weight-for-length Z scores had risen to 0.98 (84th centile) in boys and 0.76 (78th centile) in girls. At this point mean weight-for-length was significantly greater in boys than in girls ($t(793) = 4.461, P < 0.01$). Mean weight-for-length Z scores fell in both sexes after four months and by 15 months there was no longer a significant difference between boys and girls. Boys were at the 73rd centile and girls at the 70th at 15 months of age.

Rapid Weight Gain

Over the course of the first 12 months of life, 21.8% of infants in this sample showed rapid weight gain. Of these infants, 14.0% crossed one major centile band (>0.67 Z scores) and 7.8% crossed two major centile bands (>1.34 Z scores). The prevalence of rapid weight gain was not significantly different between sexes and occurred almost exclusively in the first four months.

Overweight and Obesity

While the prevalence of overweight in this sample was established early, obesity was initially low, 3.8% at one month (table 2). Obesity rose with increasing age and by 15 months 23.3% of boys and 16.7% of girls were obese. The level of overweight, however, fell from a peak of 30.5% in four month old boys and 23.0% in three month old girls to 16.1% and 14.0% in 15 month old boys and girls respectively. Combined, the prevalence of overweight and obesity peaked at 39% at 4-6 months and then fell to a nadir of 33% at 11 months before beginning to rise again in late infancy. After the first month there was a consistently greater prevalence of overweight and obesity in boys than girls until 12 months of age. After 12 months, the prevalence of overweight was similar between sexes but a greater number of boys than girls were classified as obese.

Infant Feeding and Growth

Mean weight and length curves by sex and infant feeding mode are shown in figures 3 to 6. There were significant effects of feeding at 4 (± 2 months) on weight and length. Boys who were formula-fed demonstrated a significantly faster rate of postnatal growth, gaining 1.08kg/year and 2.33 cm/year more than breastfed boys. Mixed-fed boys also gained length significantly faster than breastfed boys (1.13 cm/year). Mixed- and formula-fed girls gained weight more rapidly than breastfed girls by 0.63 and 0.60 kg/year respectively. Formula-fed girls gained 1.35cm more length per year than breastfed girls.

There were no significant differences in either birth weight or birth length by feeding mode in either sex. In the first month breastfed boys were significantly heavier than mixed-fed babies ($P < 0.05$) and both breastfed and formula-fed boys were significantly longer than mixed-fed boys. From month three onward formula-fed boys were significantly heavier than mixed-fed boys ($P < 0.01$) and from month five they were also significantly heavier than breastfed boys ($P < 0.01$). There were no significant differences in weight between breastfed and mixed-fed boys after the first month. From month two onward, formula-fed boys were significantly longer than both breast and mixed-fed boys ($P < 0.01$; Figure 4). After month 12, mixed-fed boys were also longer than breastfed boys although they were still significantly shorter than formula-fed boys. At 15 months, formula-fed boys were 1.20 kilograms heavier and 2.84 cm longer than breastfed boys.

In contrast to the consistent significant effect of feeding status on weight observed in boys, in girls there were significant differences only at one and two months and then in later infancy (13-15 months). In the first two months breastfed girls were significantly heavier than both mixed- and formula-fed girls ($P < 0.01$). In months 13 to 15 mixed-fed girls were significantly heavier than breastfed girls ($P < 0.05$). There were significant effects of feeding on length in girls. In the first three months breastfed and formula-fed girls were not significantly different but breastfed girls were longer than mixed-fed girls ($P < 0.01$). From month five onward formula-fed girls were longer than mixed-fed girls and from month eight onward they were also longer than breastfed girls ($P < 0.01$). At 15 months, formula-fed girls were 0.40 kilograms heavier and 1.35cm longer than breastfed girls.

Infant Feeding and Obesity Risk

There was little effect of feeding on weight-for-length in early infancy; only in girls was there a significant difference in mean weight-for-length Z score, with breastfed girls larger than formula-fed in the first three months ($P < 0.01$ in month one, $P < 0.05$ in months 2 and 3). In late infancy, the influence of feeding on body size was profound in boys. At 15 months the mean weight-for-length Z score of formula-fed infants was 0.49 Z scores greater than that of breastfed infants (1.11 vs. 0.62, $P < 0.01$). These mean Z scores place the average 15 month old formula-fed boy at the 87th centile according to CDC references and in the overweight category. In contrast, the breastfed infants were at the 73rd centile. In girls, there was also a significant difference between feeding groups in late infancy, the mixed-fed girls had a significantly greater mean Z score than breastfed girls (0.63 vs. 0.24, $P < 0.05$). The mixed-fed infants were at the 74th centile according to CDC references while breastfed infants were at the 59th centile.

Formula-fed boys were significantly more likely to be classified as obese at 15 months (38.6%) than breastfed boys (23.4%), $\chi^2 = 8.4$, $P < 0.01$, odds ratio = 2.05, 95% CI [1.04, 4.05]. Significant differences were not seen in girls at 15 months although overweight and obesity prevalence were greater in the mixed-fed group. More than 27% of male formula-fed infants demonstrated rapid growth compared to just 17% of breastfed and 6.4% of mixed-

fed infants ($\chi^2 = 19.4$, $P < 0.01$). In girls there was no significant difference in the prevalence of rapid weight gain according to feeding mode.

Discussion

Obesity and Associated Risk Factors

The markedly more rapid gain in weight than in length relative to the CDC observed in the early postnatal period in the present sample of Samoan infants has consequences for the prevalence of overweight and obesity. These findings suggest that highly prevalent obesity in this population is not confined to adults.

At 15 months of age, 35.2% of infants in American Samoa exceeded the CDC 85th percentile and were overweight or obese; 20.1% of them above 95th percentile and obese. Based on the CDC 2000 reference, we would expect approximately 10% of the sample to be overweight and a further 5% to be obese. The prevalence of obesity observed here was four times greater than the expected value. It was also considerably greater than that seen in infants from other countries. Ogden et al.²⁸ estimate that approximately 9.5% of US infants are obese using the same references while Nash et al.²⁹ report 16.6% of Canadian infants to be above the 85th centile.

It is noteworthy that while the prevalence of obesity increased between birth and 15 months of age, after four months of age the prevalence of overweight decreased. This suggests that infants classified as overweight in early infancy were becoming obese over time but that very few infants who remained in the normal weight range at four months were then becoming overweight. In fact, 91.1% of the infants who were normal weight at 4 months remained normal weight at 15 months. Similarly, 86.3% of infants who were obese at 4 months remained so at 15 months. It appears as though infants who can maintain normal weight in early infancy are somewhat protected against overweight and obesity in later infancy. When contrasting infants who remained normal weight at four months versus those who were overweight or obese there were no significant differences in maternal demographic characteristics, feeding mode or the prevalence of rapid weight gain between birth and four months. Infants who were normal weight at four months were, however, born lighter (3.58kgs vs. 3.78kgs, $t(793) = -3.844$, $P < 0.01$) than infants who were overweight or obese at four months. This indicates the need in future studies of Samoan infant growth to look at the pre-conception and pre-delivery periods to determine the predictors of birth weight in this population, such as maternal pre-pregnancy weight or weight gain during pregnancy which have been associated with birth weight and infant growth in other studies³⁰⁻³².

Rapid Growth

Rapid weight gain in infancy is an established risk factor for obesity³³⁻³⁶ as well as being associated with elevated blood pressure in adolescence³⁷ and metabolic syndrome and impaired glucose tolerance in adulthood³⁸. In these Samoan infants rapid weight gain is ubiquitous. In the first four months, 21.8% of infants cross more than one major weight-for-age centile band. Stettler et al.³⁴ used the same criteria for rapid weight gain in a cohort of US African American infants and found that rapid weight gain between 0-4 months was present in 29% of infants. They did not, however, condition their estimates on birth weight to account for regression to the mean as we did here. If we do not take into account weight at birth and possible regression to the mean, almost 70% of our sample crossed a major centile band in the first four months. A remarkable finding here is the magnitude of weight gain between birth and four months. In a multi-center, multi-ethnic study conducted in the US, median weight gain per month over the first four months of life was 820g³⁹, in our

study the median weight gain was 978g per month; almost 20% greater. Eight percent of Samoan infants crossed two or more major centile bands. An important but unexplored question is the existence of any additional risk for later obesity conferred with the crossing of more than one major centile band.

Rapid growth in the first four months of life is particularly characteristic of intrauterine growth restricted (IUGR) infants^{35,40}. Clearly, based on birth weight, the present sample is not characterized by IUGR, but given the rapid early post-natal growth one interpretation is that they may experience a relative growth restriction. In the context of the maternal obesity we would expect in Samoa and the consequent hyper-energetic / hyperglycemic *in utero* environment these infants may have the energetic potential to grow larger while *in utero* but are constrained by both uterine size and the evolutionary consequences of strong stabilizing selection on birth weight⁴¹. This relative constraint on *in utero* growth may result in the remarkable rapid growth postnatally we observe here. Indeed, while obesity has risen sharply in American Samoan women of childbearing age⁶ mean birth weight has not risen since the 1970s⁴². These speculations must be followed by detailed longitudinal ultrasound studies of these infants as they develop *in utero*, observing both the maternal predictors of intrauterine growth and the impact of the prenatal growth trajectory on post-term growth velocity.

Infant Feeding

In these Samoan infants formula feeding is, in boys, associated with more rapid growth in early infancy and greater overweight and obesity in late infancy. Girls who are fed a combination of breast milk and formula are at greater risk than their peers.

The finding that formula feeding is a risk factor for overweight and obesity in infancy is not new. Differences in the growth pattern of breastfed and formula-fed infants during the period of exclusive milk-feeding are well recognized¹⁵⁻¹⁷ and for this reason it has been hypothesized that breastfeeding may be protective against obesity¹⁸⁻²⁰. Several plausible mechanisms exist, both nutritional and behavioral, to explain this. Bartok and Ventura⁴³ provide a comprehensive review of the various different ways breast milk and formula differ in nutritional composition and the potential for increased obesity risk based on these differences. From a behavioral perspective, breastfeeding may promote self-regulation of energy intake by the infant⁴⁴, mothers may learn to recognize their infant's hunger and satiety cues earlier⁴⁵ and mothers who choose to breastfeed may be those who adopt other healthy dietary and lifestyle habits⁴⁶.

Mothers who choose to formula feed may also introduce solid foods at an earlier age, a behavior which is, in itself, associated with greater weight gain during infancy^{47,48} and greater weight and adiposity in childhood⁴⁹. While we replicate the general findings about infant feeding type on infant body size, the magnitude of difference between the weight and length of infants who are breast and formula-fed in late infancy is greater than previously reported, particularly in boys. In an influential paper Dewey et al.¹⁵ compared the growth of breast- and formula-fed infants in a largely white, US population and reported the mean weight of formula-fed boys to be 537g heavier and their mean length to be 0.8cm longer at 15 months than their breastfed peers. We find here that the formula-fed boys are 1200g heavier at 15 months, more than twice the estimate of Dewey et al., and 2.84cm longer. Formula-fed Samoan boys in this sample are twice as likely to be obese at 15 months of age compared to their breastfed peers, again a finding that is greater in magnitude than previously reported^{19,50}. Similar to the 362g difference shown by Dewey et al.¹⁵ formula-fed girls are 404g heavier at 15 months than breastfed girls. They are, however, 1.35cm longer than their breastfed peers, which is a much greater difference than the 0.1cm reported

by Dewey et al.¹⁵. There is no additional risk for obesity at 15 months associated with formula feeding in girls.

The fact that infant feeding practices are associated with greater weight in only boys is difficult to explain. There is little evidence to suggest that either sex has a greater susceptibility to the influence of feeding during infancy on later growth outcomes. While the preferential treatment of males is common in some Asian cultures there is nothing to suggest that this is the case in contemporary American Samoa, although our findings warrant exploration of this possibility in future studies. A recent study did show that the breast milk of mothers of male infants had a 25% greater energy content than the breast milk of mothers of female infants⁵¹. The study had, however a very small sample size (n=25) and was conducted in a largely European-derived study sample.

The association of feeding mode with obesity risk in this sample leads us to question the socio-demographic correlates of formula feeding initiation, while the magnitude of the association suggests that we should be curious about what fluids and foods, aside from formula, are being fed to these infants. The 2009 DHS for the neighboring lower-middle income country of Samoa reported very early introduction of solid foods²². More than 14% of infants had received complementary foods by one month, almost 40% by four months, with consumption of complementary foods higher in infants who were not being breastfed. More than three in four infants who were not breastfeeding received fruits and vegetables, grains, meat, fish, poultry and eggs at six months of age, 46% received foods made with oil, fat, coconut cream or butter. Detailed further study of American Samoan infant feeding is needed to understand these postnatal growth patterns and feeding choices in the context of economic and cultural modernization, especially the changing and expanding roles of women.

Limitations

The use of well baby clinic data collected by healthcare providers confers limitations of accuracy and reliability, but practitioners are likely to have had extensive experience in this local clinic. Data were rigorously examined before analysis and extreme outlying values for height (n=3) or weight (n=6) excluded.

The interpretation of these findings should be with caution since our models use a single observation of feeding mode at 4 ($\pm$ 2) months, therefore our ability to determine the direction of the relationship between feeding and obesity risk is limited. It is possible that mothers of infants being formula-fed at four months chose to change from breast to formula feeding because their babies were already fast growing and they perceived their energy needs to be greater than could be supplied by breast milk alone. Of the infants who were being breastfed at four months, a small number had at some point previously been supplemented by formula (24.8%). Similarly, in both the formula-fed and mixed-fed groups, breastfeeding exclusively had been reported at a previous time point (21.9% and 11.5% of mixed and formula-fed infants respectively). It is not unusual, for formula- and mixed-fed children to have been exclusively breastfed at some point, usually early in infancy. The models incorporating feeding as a time dependent variable did, however, show the same effect of formula feeding on growth in weight and length. While we acknowledge that the window for recording feeding mode here was wide (4 $\pm$ 2 months), particularly for this age group, it was required to maintain adequate power. The choice to use this single observation model was necessary for the estimation of obesity prevalence based on the external references.

A further limitation of this study was our inability to account for the amount of breast milk or formula being consumed by infants. Several studies suggest that total energy intake

(kilocalories) and protein intake per day are greater in formula-fed infants than in breastfed^{52,53}. Additional confounding of the association between feeding and obesity risk by unmeasured genetic, social and economic factors (as have been demonstrated in other studies) is also possible. As these data were collected from clinic records our access to socio-economic information about these participants was limited. Maternal age, years of education and occupation at the time of pregnancy were collected but these were not associated either with infant growth characteristics or with infant feeding mode in this sample. Information about other potential confounders such as maternal smoking during pregnancy were not available. The Samoan population is relatively homogenous genetically⁵⁴ but more detailed study of maternal and household social and economic factors is clearly necessary for further understanding of these remarkable patterns of infant growth.

Comparability of these findings with other studies is difficult, largely because of the use of different references for growth during this period. The CDC 2000 references were employed here for two reasons: their continued widespread use in clinical practice in American Samoa and the fact that the feeding characteristics of the CDC reference population were similar to those observed here (33% of CDC infants were breastfeeding at three months)²⁵. The more recently published WHO growth standards²⁶ provide the opportunity to compare infants to an international sample who experienced the 'optimal' environment for growth: exclusive breastfeeding and a lack of environmental constraint. While comparison with these standards for growth was not considered appropriate for this largely formula or mixed fed sample a comparison of the Samoan infants growth with these standards is provided as supplementary material.

Public Health Implications

The public health implications of this level of infant obesity are clear: evidence from other populations indicates that overweight infants become overweight children who in turn become overweight adolescents and adults¹⁴. In American Samoa, where health literacy about obesity and concomitant diseases is low and health infrastructure lacks evidence based interventions this is of critical concern⁶.

This issue is not just confined to this small island territory, Polynesians are the fastest growing population group in the US and there are large communities in Australia, New Zealand and other nations worldwide who also display highly prevalent obesity traits^{55,56}. The level of adult obesity seen in American Samoa in women of childbearing age, a probable contributor to infant obesity, is likely to foreshadow the experience of other developing countries as they undergo similar economic, demographic and nutritional transition to that experienced in American Samoa.

Gillman recently questioned whether the protective effects of breastfeeding for later obesity are generalizable outside of European-derived populations²⁴. These findings suggest that they are. If this is true, alongside its other health benefits, the promotion of exclusive breastfeeding may be a suitable cost-effective and sustainable intervention for the reduction of overweight and obesity risk in this setting. We suggest, based on these findings, that obesity prevention efforts in Samoans must be targeted at the very youngest infants with a focus on maintaining normal weight by four months of age.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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What is known about this subject

- Samoan adults are recognized for their particularly high body mass index (BMI) and prevalent obesity
- While Polynesians are understudied, in other populations infancy is a critical period in the development of obesity
- Breastfeeding has been shown to attenuate obesity risk

What this study adds

- Samoan infants show remarkably rapid gain in weight but not length in early infancy resulting in a prevalence of overweight and obesity far higher than has been previously reported elsewhere
- Breastfeeding is associated with slower weight gain in infancy suggesting that its protective benefits for obesity risk are generalizable outside of European-derived populations

Figure 1.
Mean weight-for-age, length-for-age and weight-for-length Z-scores of Samoan boys according to the CDC 2000 child growth references

Figure 2.
Mean weight-for-age, length-for-age and weight-for-length Z-scores of Samoan girls according to the CDC 2000 child growth references

Figure 3.
Mean weight curves according to feeding status at four (± 2) months: Samoan boys

Figure 4.
Mean length curves according to feeding status at four (± 2) months: Samoan boys

Figure 5.
Mean weight curves according to feeding status at four (± 2) months: Samoan girls

Figure 6.
Mean length curves according to feeding status at four (± 2) months: Samoan girls

Table 1

Description of Study Sample

	Male (n=417)	Female (n=378)	Total (n=795)
Maternal Age (years) [Mean (SD)]	28.0 (5.8)	28.2 (5.5)	28.1 (5.6)
Maternal Marital Status^a (%)			
Single	18.7	19.8	19.2
Married	81.3	80.2	80.8
Parity [Mean (SD)]	2.3 (2.0)	2.5 (2.0)	2.4 (2.0)
Parity (%)			
Primiparous	20.1	17.5	18.9
Multiparous	79.9	82.5	81.1
Delivery Type^b (%)			
NSVD	86.3	82.5	84.5
LSCS	12.1	15.8	13.9
Vacuum VD	1.6	1.7	1.6
Birth Year (%)			
2001-2002	31.7	32.8	32.2
2003-2004	24.2	22.2	23.2
2005-2006	34.5	36.8	35.6
2007-2008	9.6	8.2	8.9
Birth weight (g) [Mean (SD)]	3657.4 (469.4)	3559.3 (518.7)	3610.8 (495.6)
Birth weight Category (%)			
Low Birth weight (<2500g)	0.2	2.4*	1.3
Normal Birth weight (2500-3999g)	77.5	78.8	78.1
Macrosomic Grade I (4000-4449g)	17.5	15.6	16.6
Macrosomic Grade II (4500-4999g)	3.8	2.9	3.4
Macrosomic Grade III (≥5000g)	1.0	0.3	0.6
Birth Length (cm) [Mean (SD)]	51.4 (1.9)	50.1 (2.1)	51.0 (2.0)
Gestational Age (weeks) [Mean (SD)]	39.9 (1.1)	39.9 (1.1)	39.9 (1.1)
Gestational Age Category (%)			
37 weeks	4.6	5.8	5.2
38 weeks	15.8	13.5	14.7
39 weeks	22.8	21.7	22.3
40 weeks	56.8	59.0	57.9
Feeding Mode at 4 (±2) months^c (%)	(n=336)	(n=306)	(n=642)
Breastfeeding	28.0	28.4	28.2
Formula Feeding	20.8	18.3	19.6
Mixed Feeding	51.2	53.3	52.2

* χ^2 between sexes: $P < 0.05$

^a Single = single, divorced, widowed, separated; Married: married, cohabiting, partner

^b NSVD = Normal Spontaneous Vaginal Delivery; LCSC = Lower Segment Caesarean Section; Vacuum VD = Vacuum Vaginal Delivery

^c Breastfeeding includes exclusive breastfeeding and breastfeeding supplemented with water

Table 2
Prevalence of overweight and obesity in Samoan infants based on the CDC 2000 growth references and WHO growth standards

Age	Male (n=417)				Female (n=378)				Total (n=795)			
	CDC		WHO		CDC		WHO		CDC		WHO	
	OW (%)	OB (%)	OW (%)	OB (%)	OW (%)	OB (%)	OW (%)	OB (%)	OW (%)	OB (%)	OW (%)	OB (%)
1 month	10.8	3.1	20.1	10.8	16.7	4.5	22.8	14.3	13.6	3.8	21.4	12.5
2 months	25.7	8.6	21.1	12.7	22.0	6.6	20.4	12.2	23.9	7.7	20.8	12.5
3 months	29.0	14.4	23.3	15.8	23.0	7.9	20.1	11.1	26.2	11.3	21.8	13.6
4 months	30.5	17.0	25.7	17.5	21.4	8.2	19.6	11.4	26.2	12.8	22.8	14.6
5 months	28.8	18.5	25.4	18.5	22.0	8.5	18.8	11.1	25.5	13.7	22.3	15.0
6 months	27.8	18.9	24.7	17.7	20.1	9.0	16.7	11.6	24.2	14.2	20.9	14.8
7 months	25.4	18.7	23.7	17.5	17.7	9.8	16.9	11.6	21.8	14.5	20.5	14.7
8 months	23.3	18.5	22.3	17.5	16.7	10.6	17.5	11.9	20.1	14.7	20.0	14.8
9 months	21.6	18.5	20.6	19.7	15.9	11.1	17.2	13.2	18.9	15.0	19.0	16.6
10 months	20.1	18.5	19.4	21.3	15.1	11.6	17.7	14.3	17.7	15.2	18.6	18.0
11 months	18.9	19.2	20.4	21.3	14.0	12.4	19.0	15.9	16.6	16.0	19.7	18.7
12 months	17.5	19.9	19.7	22.8	15.1	13.0	21.4	16.7	16.4	16.6	20.5	19.9
13 months	16.9	21.1	19.7	23.7	15.0	13.9	21.2	19.0	16.0	17.6	20.4	21.5
14 months	16.1	22.1	19.7	25.2	14.6	15.1	21.4	20.4	15.3	18.7	20.5	22.9
15 months	16.1	23.3	20.1	26.6	14.0	16.7	21.7	22.2	15.1	20.1	20.9	24.5

Overweight (OW): Weight-for-length > 1.04 Z scores 1.64 Z-scores (85th centile); Obese (OB): Weight-for-length > 1.64 Z-scores (95th centile) NB. Overweight estimates do not include obese individuals

Table 3Weight Status at 15 months and Rapid Growth in Infancy by feeding status at 4 (± 2) Months

	Breastfeeding	Formula Feeding	Mixed Feeding
Male (n)	94	70	172
<i>Weight Status [n (%)]</i> **			
Normal Weight	59 (62.8)	38 (54.3)	108 (52.8)
Overweight	13 (13.8)	5 (7.1)	28 (16.3)
Obese	22 (23.4)	27 (38.6)	36 (20.9)
<i>Rapid Growth [n (%)]</i> **			
0-4 Months	16 (17.0)	19 (27.1)	11 (6.4)
Female (n)	87	56	163
<i>Weight Status [n (%)]</i>			
Normal Weight	69 (79.3)	42 (75.0)	108 (66.3)
Overweight	10 (11.5)	8 (14.3)	27 (16.6)
Obese	8 (9.2)	6 (10.7)	28 (17.2)
<i>Rapid Growth [n (%)]</i>			
0-4 Months	14 (16.1)	8 (14.3)	21 (12.9)

Overweight: Weight-for-length > 1.04 Z scores 1.64 Z-scores (85th centile); Obese: Weight-for-length > 1.64 Z-scores (95th centile). Rapid weight gain: Conditional gain > 0.67 Z scores

* χ^2 between feeding groups: $P < 0.05$;

** $P < 0.01$

NB. Overweight estimates do not include obese individuals