AMERICAN JOURNAL OF HUMAN BIOLOGY 23:325–332 (2011)

Original Research Article

Altered Growth Patterns of a Mountain Ok Population of Papua New Guinea Over 25 Years of Change

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Context: The Mountain Ok (Mt Ok) people of Telefomin, who live at the interior of Papua New Guinea (PNG), were documented over 25 years ago to be one of the shortest populations on record, with average adult height below the fifth percentile (US). Serum Growth Hormone was detectable, Insulin-like Growth Factor-1 and serum indicators of protein nutritional status fell within the normal range, suggesting that these were not primary factors for their relative short stature.

Objective: Since the Telefolmin people have experienced recent socioeconomic changes, they were re-evaluated in 2008, to examine height, weight, and body mass index (BMI), for insight into relative contributions of environment and other factors that modulate stature in children and adults.

Study Design and Setting: Cross-sectional anthropometric data were collected from 474 individuals at Telefomin in 2008, and compared with anthropometric data from 342 individuals measured in 1983.

Results: The height of Telefolmin subjects, below the fifth percentile in 1983, remained below the fifth percentile in 2008. Weight and BMI of peripubertal and adult age groups increased from 1983 to 2008. Male and female heights at peripubertal ages were significantly greater in 2008. Nevertheless, final adult height did not change significantly over the 25 years.

Conclusions: Recent socioeconomic changes appear to contribute to increased weight, BMI, and stature at younger ages in the Mt Ok at Telefomin. In contrast, unchanging adult stature may reflect a delay in the impact of socioeconomic changes, or genetic influences that modulate responsiveness to other growth regulators. Am. J. Hum. Biol. 23:325–332, 2011.

Among the complexities determining stature in human populations are environmental, nutritional, hormonal, and genetic factors. For insight into stature regulation, it is often informative to focus on populations where stature is generally at extremes of the normal distribution (Bogin, 1988; Walker et al., 2006). The Mountain Ok (Mt Ok) people at Telefomin, at the interior of Papua New Guinea (PNG), were found to be one of the shortest on record when they were studied in 1983, with heights below the fifth percentile at all ages (Schwartz et al., 1987). In this population, detectable serum levels of Growth Hormone were sufficient to induce average IGF-1 levels within the normal range. Serum indicators of protein nutritional status were also within normal ranges (Schwartz et al., 1987). These observations suggest that inadequate serum levels of key hormones and protein deficiency are not primary factors for the relative short stature of the Mt Ok people.

PNG has experienced many socio-economic changes in the time since World War II. For Telefomin, establishment of the Ok Tedi gold and copper mine in a nearby area in the early 1980s (Jackson, 1982) introduced cash economy and elements of modern lifestyle to this society, which until then was based primarily on traditional subsistence horticulture and hunting (Jorgensen, 2006). To assess whether growth patterns in children and adults in this population have changed after 25 years, anthropometric parameters of the Telefolmin people were measured in 2008 and compared with the measurements obtained in 1983. This comparison provides insight into changes in height and weight, indicative of socioeconomic changes that have occurred in this population over the past 25 years.

MATERIALS AND METHODS

Subjects and Data collection

All aspects of this study conform to an IRB protocol approved by the University of Michigan, and were approved by the Medical Research Advisory Committee, PNG Dept of Health, through the PNG Institute of Medical Research. The Telefol-speaking Mt Ok population at Telefomin, numbering ~4,500, resides at the interior of PNG in West Sepik Province. Data in the present study include only Telefol-speaking subjects from Telefomin, Feranmin, and Elliptaman, referred to here collectively as Telefolmin. Male and female Telefolmin subjects were recruited as volunteers at Telefomin schools, clinics, and community centers. Cross-sectional data were collected from a total of 474 individuals, including 376 children (below 20 years) and 98 adults (Table 1). Height (cm) was measured with subjects standing barefoot on an upright stadiometer (accuracy ± 1 mm). A digital scale (accuracy ± 0.1 kg) was used to measure weight (kg)

Additional Supporting Information may be found in the online version of this article.

Contract grant sponsor: Office of the Vice President for Research and the Department of Molecular and Integrative Physiology, University of Michigan; Contract grant sponsor: NIH training grant in Developmental Origins of Endocrine Dysfunction; Contract grant number: T32 DK071212.

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Received 29 June 2010; Revision received 29 September 2010; Accepted 12 October 2010

DOI 10.1002/ajhb.21134

Published online 22 December 2010 in Wiley Online Library (wileyonlinelibrary.com).

with subjects lightly clothed. Body mass index (BMI) was calculated as weight divided by height^2 (kg/m^2). Mid-upper-arm circumference (MUAC, cm) measured at the mid-upper left arm, and armspan, were obtained using a tape measure. Anthropometric data obtained by the same investigators in 1983, using similar equipment and procedures (Schwartz et al., 1987), were re-analyzed for subjects at Telefomin according to inclusion criteria used in 2008. Ages provided by the participants or by school administrators were verified from birth registries and hospital records when available, as well as from a calendar of local events.

Statistical analysis

Mean height, weight, and BMI were calculated for individual ages, and for adults grouped in 5-year intervals for the 2008 cohort. Growth curves were plotted relative to US (http://www.cdc.gov/GROWTHcharts/) and WHO (www.who.int/childgrowth/standards) standards. To compare 2008 data to those collected in 1983, data were stratified into 5-year intervals for individuals below 20 years of age (Table 1, Table S1). In the present discussion, ages 6–15 years in females and 11–20 years in males are referred to as "peripubertal" age groups. For adults, subgroups included subjects 21–25 years old; in the 2008 cohort, these individuals were born after the Ok Tedi mine opened. Additional adult age groups were stratified in 10-year intervals up to 45 years of age, with an additional group above 45 years of age, when bone loss might impact stature. Standardized Z scores for height, weight, and BMI were calculated for individuals younger than 20 years using the CDC Z score calculator tool (http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm).

TABLE 1. Mt Ok study cohorts in 2008 and 1983

	Male		Female	
Age group (Years)	2008	1983	2008	1983
0–5	24	20	22	11
6–10	51	13	42	17
11–15	67	17	89	29
16–20	36	23	45	37
21–25	11	3	12	17
26–35	14	14	15	27
36–45	18	19	10	32
>46	9	38	9	25
Total	230	147	244	195

For the analysis of anthropometric data, subjects were grouped by age in intervals of 5 years to age 25, and intervals of 10 years above age 25. Total number of subjects were 474 in 2008 and 342 in 1983 cohort. Table shows numbers of subjects in age groups, by study year and gender.

Statistical analyses were performed separately for males and females using SPSS version 16 or 18 (SPSS Inc) and STATA version 10 (StataCorp LP). Two-sample t tests were performed to compare the raw means and standardized Z scores for height, weight, and BMI in each age group. Pearson correlation coefficient was calculated using SPSS to relate armspan with height, as well as MUAC with BMI; the latter are both considered to correspond with nutritional status (Chomtho et al., 2006; Ferro-Luzzi and James, 1996). To assess the changes in height, weight, and BMI from 1983 to 2008, a linear regression model was used with height/weight/BMI as dependent variable, and cohort indicator as the primary predictor. To accommodate variable growth patterns across the human lifespan, a piecewise linear structure of age, a special case of Spline (Hastie and Tibshirani, 1995), was used, with age intervals defined above. Results of QQ plots and histograms indicated that data for weight and BMI were slightly skewed; accordingly log transformations for weight and BMI were used as outcomes for the linear regression analysis. To evaluate differences in patterns of change between 1983 and 2008 for subjects in the different percentile groups, quantile regression analysis (Koenker, 1982) was carried out for height, weight, and BMI for subjects in the 90th, 50th, or 10th percentiles. Values of $P < 0.05$ were considered statistically significant.

RESULTS

Height of Telefolmin subjects falls below the fifth percentile

Average height of Telefolmin adult age groups fell below the fifth percentile, for both males and females, in 1983 (Schwartz et al., 1987) and again in 2008 (Fig. 1). The relatively short stature was observed when expressed relative to US (Fig. 1) or to WHO (data not shown) growth charts. The adult mean (± SD) heights for individuals 21–

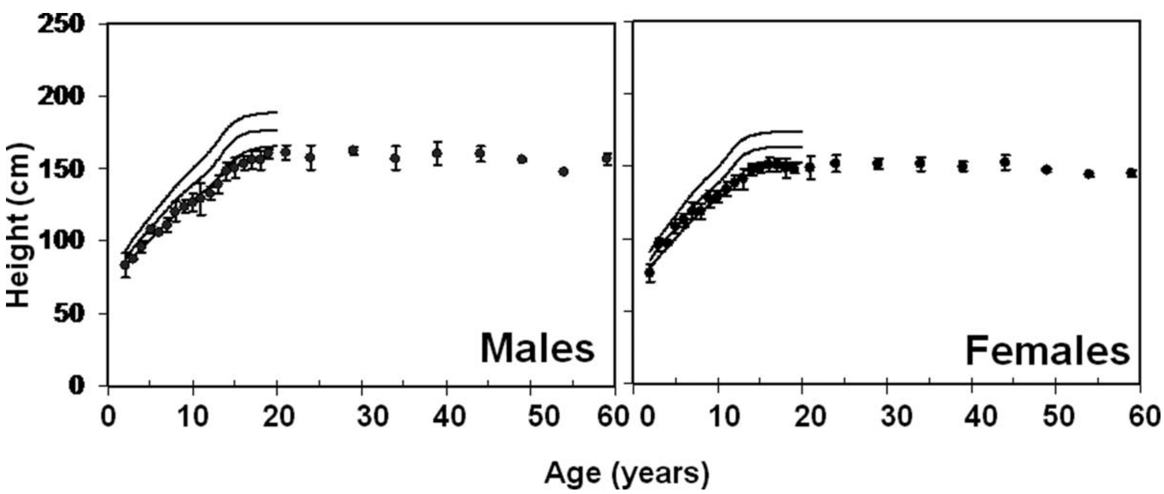

Fig. 1. Height of Mt Ok people falls below fifth percentile in 2008. Growth curves for Telefolmin males (A) and females (B) are plotted as mean height (cm) for age (year) in comparison to US growth charts indicated by dotted lines for the 5th (lower), 50th (middle), and 95th (upper) percentiles. Points show Mean ± SD for individual ages (below 20 years) or at the midpoint of 5-year age intervals above 20 years.

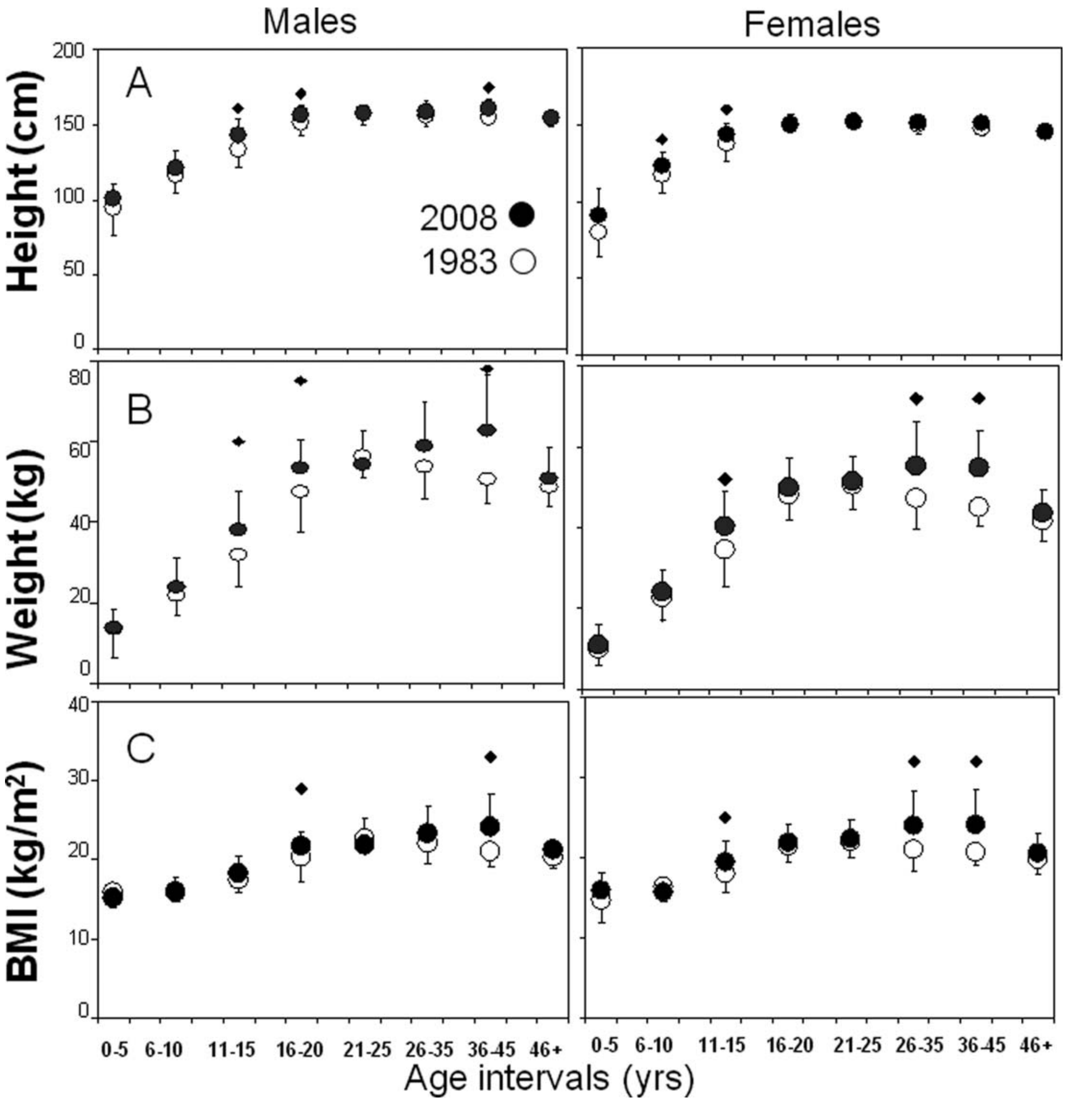

Fig. 2. Height, weight, and BMI of Telefolmin are higher at peripubertal ages in 2008 than in 1983. Mean height (A), weight (B), and BMI (C) of Mt OK males and females are significantly greater at peripubertal ages ($P < 0.05$ shown by ◆) in 2008 (solid circles) versus 1983 (open circles). Weight and BMI are also significantly greater in some adult age groups in 2008 as indicated. Each point shows mean height (±SD) for age groups in Table 1.

40 years of age in 2008 are 158.8 ± 6.6 cm for males (n = 35) and 151.4 ± 4.6 cm for females (n = 33). Corresponding Z scores indicate standard deviations of −2.5 and −1.8 relative to US standard, consistent with stature below the fifth percentile.

For children, the mean heights fell below the fifth percentile for both males and females above 10 years old. In children from 0 to 10 years old, the mean heights in 2008 approached the 50th percentile, particularly in females. In subjects of all ages, measurements of armspan correlated with measurements of height (r = 0.96; Fig. S1), consistent with proportionate growth.

Height is greater at peripubertal ages in 2008

Height measurements in 2008 were compared to those from Telefolmin subjects in equivalent age groups in 1983 (Fig. 2A). The adult heights of Telefolmin subjects, based on measurements in subjects from 21 to 40 years old, were not significantly different in 1983 and 2008. It is of note that in 21–25 years old subjects whose early growth occurred after the Ok Tedi mine was in operation, neither male nor female height was significantly different in 2008 compared to 1983 (Fig. 2A, Table S1). When adult values are compared for 10-year age intervals, height was significantly greater only in the 36–45-year age group for males.

For subjects below 20 years, however, it was notable that a significant increase in average height was observed in 2008 relative to 1983 measurements (Fig. 2A): For males, height was significantly greater in 11–15 years (9 cm difference) and 16–20 years (4.8 cm difference) age groups; for females, height was significantly greater at 6–10 years (6 cm difference) and 11–15 years (6 cm difference) groups. These age groups in males and females are collectively referred to here as "peripubertal." The earlier onset of the height increase in females is consistent with the typical earlier age of puberty in females than in males (Lee and Houk, 2007). For these peripubertal age groups, Z

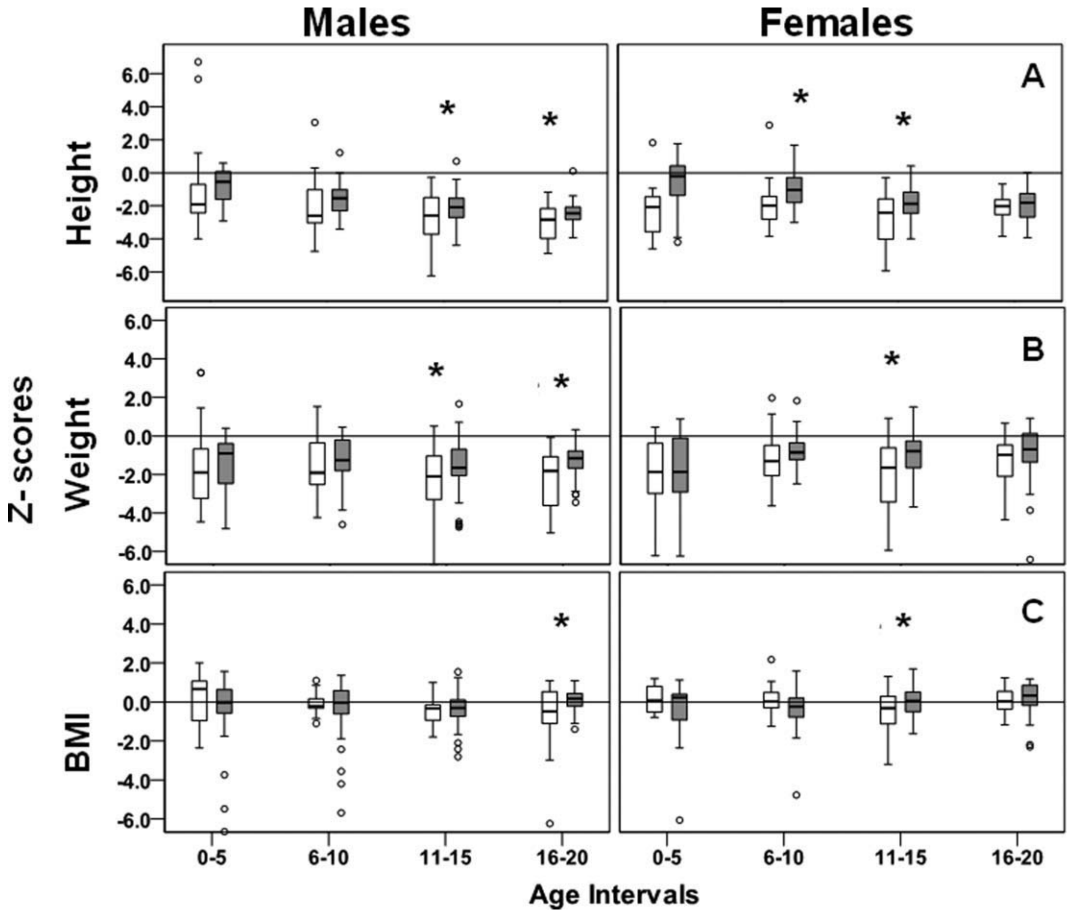

Fig. 3. Z scores for height, weight, and BMI of Telefolmin are higher at peripubertal ages in 2008. Z scores normalizing Mt Ok data to US values (reference line = 0) are shown for subjects below 20 years, grouped as in Figure 2. Height, weight, and BMI were significantly greater in 2008 (gray box) versus 1983 (open box) for age groups indicated on x axis ($P < 0.05$ shown by *). Each box shows median (horizontal line) within 25th (bottom) and 75th (top) percentiles; error bars show 5th (bottom) to 95th (top) percentiles. Small open circles show outliers.

scores for height were also significantly greater in 2008 than 1983 (Fig. 3A). Peak height velocity was estimated based on the regression coefficient for height (Table 2A). The period of the most rapid pubertal growth was observed during the 11–15 years interval for males, at 4.7 cm/year ($P < 0.005$), and for the 6–10 years interval for females, at 4.4 cm/years ($P < 0.005$). Thus, Telefolmin individuals in the peripubertal age groups are significantly taller in 2008 compared to their 1983 counterparts, based on subgroup analysis of individual age groups (Table S1).

Increases in height from 1983 to 2008 were also noted in the 0–5 years age group. The magnitude of increases in height in this age group (6.6 cm for males and 10.8 cm for females) is greater than the increases in height in the peripubertal age groups. However, the increases in mean height for 1983 and 2008 did not show statistical significance in the 0–5 years age group, which may be related to the smaller sample size.

Weight and BMI of Mt Ok adolescents and adults increased in 2008 compared to 1983

Body weight and BMI were greater in adults in 2008 compared to 1983 when controlled for the piecewise linear structure of age in the multiple regression framework. The males and females in the 2008 study overall weighed 7% and 9% more on average, respectively, than the corresponding 1983 cohort ($P < 0.02$) based on regression analysis (not shown). The BMI was on average 4% greater ($P < 0.05$) in males and 5% greater in females ($P < 0.005$) in 2008 than in 1983. When weight and BMI data for adults were analyzed by age intervals, the increases were significant for males 36–45 years and females 26–35 and 36–45 years (Fig. 2B, C). For peripubertal ages, the average body weight also increased significantly in 2008 compared to 1983. Males from 11 to 15 and 16 to 20 years old were significantly heavier (Fig. 2B); the corresponding BMI was significantly greater in 2008 in 16–20-year old males ($P = 0.029$). Females showed a significant increase in weight and BMI at 11–15 years ($P = 0.008$). For ages 20 years or less, the corresponding Z scores for weight by age and gender are also significantly higher in 2008 compared to 1983 (Fig. 3). Z scores for BMI in both the 1983 and 2008 cohorts are closer to the US standard values, and generally show less variability, than Z scores for height and weight; these characteristics suggest that their weight is in proportion to their stature. The Pearson correlation coefficients relating BMI and MUAC were 0.92 for males and 0.87 for females (Fig. S2), as would be expected since both MUAC and BMI are considered to correspond with nutritional status.

In evaluating the pattern of changes in weight and BMI across all age intervals, regression analysis revealed that the greatest weight gain of 11% ($P < 0.005$) occurred around the age of 11–15 years in males and females (Table 2B). For BMI, the increase was also greatest in the 11–15 years age group, increasing by 4% ($P = 0.01$) for males and 5% ($P = 0.01$) for females. Thus, the increases in height of adolescent age groups between 1983 and 2008 are accompanied by increases in weight and BMI in the same age groups.

Relationships between increased height and weight are not parallel

For a comprehensive evaluation of the patterns of relative changes in height, weight, and BMI over the 25 years spanned in this study, quantile regression analyses were carried out comparing subjects in 10th, 50th, and 90th percentiles for each parameter, to estimate the percent change between the 1983 and 2008 subjects (Fig. 4). Within the 50th percentile group, the percentage increase in weight and BMI for both males and females is greatest and is accompanied by a comparable percentage increase in height. For subjects in the 10th percentile, the percent increase in height was greater than the percent increase in weight or BMI. In contrast, for subjects in the 90th percentile, the percent increase in height was substantially smaller than the percent increase in weight. These observations, for both males and females, suggest that subjects in the 90th percentile achieved less percent increase in height despite a substantially greater percent increase in weight.

TABLE 2. Estimated changes in height, weight, and BMI by age group

Age group (Years)	Male	Female
A		
Height		
0–5	8.27 ± 1.0	9.44 ± 0.60
6–10	3.87 ± 0.42	4.4 ± 0.37
11–15	4.73 ± 0.35	4.06 ± 0.25
16–20	1.79 ± 0.38	0.56 ± 0.24
20–45	−0.02 ± 0.08	−0.11 ± 0.06
>46	−0.23 ± 0.11	−0.23 ± 0.1
B		
Log weight		
0–5	0.23 ± 0.02	0.24 ± 0.01
6–10	0.07 ± 0.01	0.08 ± 0.01
11–15	0.11 ± 0.01	0.11 ± 0.01
16–20	0.06 ± 0.01	0.02 ± 0.01
20–45	−0.002 ± 0.002	−0.004 ± 0.002
>46	−0.006 ± 0.003	−0.008 ± 0.003
Log BMI		
0–5	−0.01 ± 0.01	0.01 ± 0.01
6–10	0.01 ± 0.01	0.01 ± 0.01
11–15	0.04 ± 0.01	0.05 ± 0.01
16–20	0.03 ± 0.01	0.02 ± 0.01
20–45	−0.002 ± 0.001	−0.002 ± 0.001
>46	−0.003 ± 0.002	−0.005 ± 0.002

A: Estimated rate of change in height (cm/year) for each age group (year) are based on the regression coefficients shown ± standard errors. Peak change for males occurs at 11–15 years and for females at 6–10 years.B: Estimated rate of change in weight (percentage/year) and BMI (percentage/year) for age groups are based on the regression coefficients shown for log transformation of weight and BMI values ± standard errors. Peak changes in weight and BMI occur in 11–15 year group for males and females.

DISCUSSION

Stature of the Mountain Ok at Telefomin

The Mt Ok people at Telefomin as a population have relatively short stature, which for adults generally falls below the fifth percentile for height. This was observed in 1983 and in 2008. Since key growth-promoting hormones GH and IGF-1 were detectable in their serum, and serum protein nutritional indicators fell in a normal range (Schwartz et al., 1987), inadequacies of these parameters are not key factors in their relatively short stature. Studies of other populations with stature comparable to that of the Telefolmin also report detectable serum GH, although reports of adequacy of IGF1 and components of the GH-IGF axis are variable (Clavano-Harding et al., 1999; Dulloo et al., 1996; Merimee et al., 1981, 1982). A recent report suggests that reduced GH receptor gene expression may contribute to reduced circulating IGF-1 levels reported in African Pygmy subjects (Bozzola et al., 2009). Reduced GH receptor gene expression may correspond with reduced levels of circulating GH Binding Protein (GHBP) reported for Pygmy populations in Africa and the Philippines (Baumann et al., 1989; Davila et al., 2002); Telefolmin subjects also had reduced GHBP (Baumann et al., 1991) with average IGF1 in the normal range (Schwartz et al., 1987), suggesting that multiple factors impact regulation of stature by these hormones in various populations. The present study analyzed anthropometric

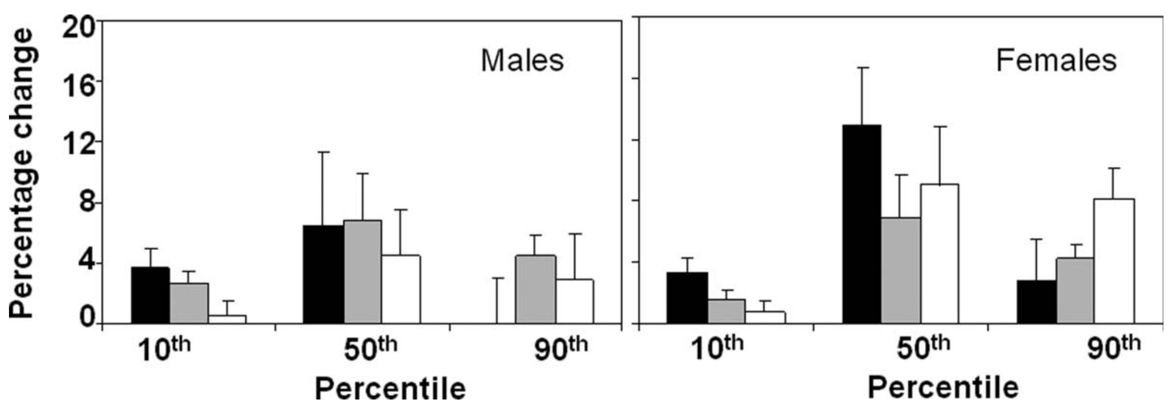

Fig. 4. Percent changes in height are not parallel to changes in weight and BMI. The relationships among percent changes between 2008 and 1983, for height (black bar), weight (gray bar), and BMI (open bar), vary among the shortest (10th percentile) and tallest (90th percentile) subjects. Values are presented as Mean ± SD, derived from quantile regression analysis.

measurements in children and adults at the beginning and end of a 25-year-interval during a period of rapid socioeconomic changes in the Telefomin area, to gain insight into other factors that contribute to stature in this population.

Younger age groups show increased height over the 25-year-interval

Comparison of anthropometric data for the Telefolmin people indicates that height in children younger than 5 years and around the time of puberty is greater in both males and females in 2008 compared to 1983. In children younger than 5 years of age, the increase in height (6.6 cm for males and 10.8 cm for females) did not show statistical significance. This may be related to the smaller sample sizes in the <5-year age group. A rapid increase in growth was noted among the females in the 6–10-year-interval and males in the 11–15-year-interval. The observed increases in height at Telefomin occur at an earlier age in girls (6–10 years) than in boys (11–15 years), as would be expected in the context of the typical earlier puberty in females. These age groups are referred to as peripubertal, since no systematic data are available on the pubertal status of individuals in this population. Though these age groups may be younger than previously reported in some PNG populations to be undergoing puberty (Groos and Smith, 1992), the overall growth pattern appears to be consistent with a pubertal growth spurt. The increases in height in these peripubertal age groups over the 25 years (5–9 cm for males and 6 cm for females) were statistically significant. The increases were modest when compared to some studies of adolescents in other parts of the world that report height increases in the range of 5–10 cm per decade (Cardoso, 2008; Kurokawa et al., 2008). The magnitude of the estimated pubertal growth spurt in Telefolmin males and females is modest compared to the 8–9 cm per year growth velocity typically seen during puberty in US children (Abbassi, 1998). One can speculate that the relatively modest growth spurt among the Mt Ok at Telefomin reflects relatively lower responsiveness at the growth plate to pubertal hormones. Nevertheless, the height of subjects at peripubertal ages in the population at Telefomin is significantly greater in 2008 than it was 25 years earlier. In addition, the increases in height in children younger than 5 years and in the peripubertal groups may be an indication that this population is experiencing a secular trend in height suggested by height increases in children with changes in socioeconomic status.

Weight and BMI increase in young and adult age groups

Although adult height exhibits high heritability (Carmichael and McGue, 1995; Perola et al., 2007; Silventoinen et al., 2003), it is well recognized that environmental factors influence stature. In developing nations, rapid socioeconomic changes can be associated with altered nutrition, including increased caloric intake, and with more sedentary activity. These secular trends can impact growth patterns during periods of socioeconomic change, where progressive increases in height and weight are often reported (Bogin, 1988; Cardoso, 2008; Cavelaars et al., 2000; Hoppa and Garlie, 1998; Juliusson et al., 2007; Komlos et al., 2009; Marques-Vidal et al., 2008; Meszaros et al., 2008). In PNG, secular trends in height and weight have been reported, but are variable, often depending on the region (Norgan, 1995; Tracer et al., 1998; Ulijaszek, 1993; Zemel and Jenkins, 1988).

The Telefolmin have experienced increases in both weight and BMI over the 25-year-period from 1983 to 2008. Weight and BMI increased in both peripubertal and adult age groups over the 25-year-span, in contrast to height which increased only in the peripubertal age groups. Interestingly, both males and females showed patterns of early weight gain with a concurrent increase in height, suggesting that weight gain, reflecting increased caloric intake, was contributing to height increase during this early period. In later adolescence, the BMI continued to increase, suggesting that during this period of decreased growth velocity, weight gain was not contributing to height. Since maintenance of body weight is dependent upon a balance between caloric intake and expenditure, the increased weight and BMI may be a reflection of altered lifestyle and increased access to a diet containing commercial rather than traditional foods (Jorgensen, 2006).

Impact of interactions with Ok Tedi mine: Socioeconomic changes

A major socioeconomic development in the time between 1983 and 2008 has been the opening of the Ok Tedi mine (Jackson, 1982). The impact of the mine is one factor likely to have contributed to increased height, weight, and BMI observed at Telefomin over the 25 years. Maximal adult height, which is expected to be attained by 20–25 years, did not change significantly from 1983 to 2008. A significant height increase among 36–45-year old males might reflect sudden but transient changes in socioeconomic conditions at the time the Ok Tedi mine was first established, since this age group is estimated, by extrapolating longitudinally from cross-sectional data, to have been experiencing pubertal growth at that time. However, one can also conjecture that the relative height increase in this age group may be related to sample size, or reflect factors such as earlier onset of bone loss in the subjects in the 1983 study, or other unrecognized factors.

Changing socioeconomic conditions can affect birth weights through their impact on maternal health and nutrition (Stephenson and Symonds, 2002). Birth weights of 531 Telefolmin infants across several decades (1963–2000) were obtained from hospital and mission records. The mean birth weights (±SD) of 2747 ± 532.7 are not considered low birth weight (<2,500 g). No significant difference was found by comparing all birth weights pre-1984 to all post-1984 when Ok Tedi began mining operations in the area. However, comparison of birth weights (Mean ± SD) for the early interval 1963–1970 (2663.9 ± 526.8 g, $n = 124$), which predated impact from Ok Tedi mine, and the recent interval 1995–2000 (2854.9 ± 595.3 g, $n = 104$) did reveal a significant increase ($P < 0.01$). Similar birth weights have been reported in another region of West Sepik Province, where changes in socioeconomic conditions suggested a secular trend in birth weights (Tracer et al., 1998). Analysis of Mt Ok data therefore suggests that changes in birth weight may reflect a change in socioeconomic conditions between 1963 and 2000.

For perspective in interpreting the changes in growth patterns at Telefomin between 1983 and 2008, an important comparison is provided by a set of anthropometric studies of the Wopkaimin, carried out in 1982 and 1983 to provide a baseline for the Ok Tedi Health and Nutrition Project (Hyndman et al., 1989; Lourie et al., 1986; Ulijaszek et al., 1989). The Wopkaimin are Mountain Ok speakers, closely related to Telefolmin in language and culture, who live in the immediate vicinity of the Ok Tedi mine. Previously more remote and inaccessible than Telefomin, this area was dramatically transformed by the development and opening of the Ok Tedi mine (Hyndman, 1994; Hyndman et al., 1989; Lourie et al., 1986).

Wopkaimin stature is similar to that observed at Telefomin: adult height (21–25 year olds) reported for Wopkaimin in 1982–1983 (males 159.6 ± 5.2 cm, females 149.5 ± 4.4 cm) does not differ significantly from the height for this age group at Telefomin in 1983 or 2008. No change in adult height of Wopkaimin was reported in a follow-up study 3 years later (Hyndman, 1994).

Although the Ok Tedi mine began full operation in 1984, at which time its impact was felt in Telefomin, the Wopkaimin had been involved for some years previously in setup work for the mine. The studies of Wopkaimin carried out in 1982–1983 found that factors associated with increased height and weight include age, employment by the mine, and residential proximity to the mine (Lourie et al., 1986), all consistent with increased availability of food (Lourie et al., 1986).

Consistent with findings at Telefomin that serum protein levels suggest dietary protein adequacy (Schwartz et al., 1987), detailed intake studies found no shortage of protein in the Wopkaimin diet (Brand et al., 1991; Ulijaszek and Pumuye, 1985). Although the Wopkaimin and Telefolmin situations are not identical, results of the studies in both groups suggest that the presence of the Ok Tedi mine has promoted changes in diet, including higher caloric intake, which are consistent with increased weight and height. However, neither Wopkaimin in 1983, nor Telefol in 2008, exceeded the mean adult height observed at Telefomin in 1983.

The unchanged adult height observed in our studies is reminiscent of other observations in PNG of an increased tempo of growth in height and weight among adolescents which was not reflected in an increase in height of adults (Zemel and Jenkins, 1989). In the present study, unchanged adult height over 25 years, in the context of socioeconomic changes that do impact stature in younger age groups, raises the possibility that genetic factors limit stature in the Mt Ok populations.

Multiple factors influence stature of the Telefolmin

Adult height of the Telefolmin has not changed significantly over the last 25 years, despite the increase in height at peripubertal ages observed in 2008. This may reflect a time lag, whereby new conditions associated with socioeconomic development, such as changes in nutrition and physical activity began to have an impact on growth patterns only recently. It remains to be seen whether the trend of increased height of young children and adolescents as well as an increase in birth weight (Varela-Silva et al., 2009) will be reflected in an increase in adult height in the near future. Such a delay would be somewhat surprising, given the apparent impact of Ok Tedi mine at Telefomin as early as 1984, which would have been expected to impact growth of subjects who were 21–25 years old in 2008. Alternatively, genetic factors limiting increases in stature may be involved. This would be consistent with the observation that height measurements for the tallest subjects (90th percentile) showed the least percent increase between 1983 and 2008; this group also showed less percent increase in height compared to the increase in weight. These observations suggest that there may be a genetic influence on maximal height potential for this population, so that further environmental and nutritional changes can increase weight and BMI, but contribute progressively less to stature. It is established that adult height exhibits high heritability, ranging from 0.75–0.9 (Carmichael and McGue, 1995; Perola et al., 2007; Silventoinen et al., 2003). Recent approaches to understanding the genetics of height include linkage analysis and genome wide association studies (GWAS) of populations of varying stature throughout the world; these have identified single nucleotide polymorphisms (snps) in loci that are thought to be associated with stature variation in general populations (Lettre, 2009; Weedon and Frayling, 2008). The multiple factors influencing stature, including endocrine regulators such as the GH-IGF axis, emphasize the value of integrating various approaches, including genomic studies, with the prior (Schwartz et al., 1987) and present studies of populations such as the Mt Ok at Telefomin and similar studies of other populations.

In summary, this study reveals that, after 25 years, stature of Telefolmin adults remains below the fifth percentile. However, height has increased in peripubertal age groups. Body weight and BMI increased not only in peripubertal but also in most adult age groups. Thus, growth patterns are changing within the Mt Ok population at Telefomin. Recent socioeconomic changes are likely to have contributed to their increased weight, BMI, and stature at younger ages. The unchanging adult stature may reflect a delay in the impact of socioeconomic changes, or genetic influences that limit responsiveness to other growth regulators.

ACKNOWLEDGMENTS

The co-operation and participation of the people of Telefomin is greatly appreciated. The authors thank Ella Dikinsep, Jerry Katolok, and the staff of the Telefomin District Hospital; the Telefomin District Government, the PNG Institute of Medical Research, and the Health Department of Papua New Guinea for their valuable assistance during the field portion of the study. The authors also thank Drs. M. Meisler, R. Menon, J. Lee, and B. Strassmann for helpful comments and discussions during the preparation of the manuscript.

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