AMERICAN JOURNAL OF HUMAN BIOLOGY 00:000–000 (2008)

Original Research Article

Taller Women do Better in a Stressed Environment: Height and Reproductive Success in Rural Guatemalan Women

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ABSTRACT Previous research on the relationship between height and reproductive success in women has produced mixed results. One possible explanation for these is mediation by ecological factors, such as environmental stress. Here we investigate female height and reproductive success under conditions of environmental stress (poverty) using a large scale dataset from Guatemala ($n = 2{,}571$). Controlling for educational attainment, age and ethnicity, we examined relationships between height and childlessness, occurrence of a stillbirth, fertility and child survival. There was no significant relationship between height and never haven given birth. Extremely short women had a significantly raised likelihood of experiencing stillbirth. There were curvilinear relationships between height and age at first birth, fertility, and survival rates for children. Overall, though, the penalties for short stature, particularly in terms of child survival, were far greater than those associated with extreme tallness, and so female height is positively associated with overall fitness in this population. Am. J. Hum. Biol. 00:000–000, 2008.

In men, tallness is related to socioeconomic status and good health (Bielecki and Szklarska, 1999; Kuh and Wadsworth, 1993; Macintyre and West, 1991; Magnusson et al., 2006; Mascie-Taylor and Lasker, 2005; Silventoinen et al., 1999; Szklarska et al., in press; Teasdale et al., 1991). Height also has a positive influence on male mating and reproductive success in some Western populations (Mueller and Mazur, 2001; Nettle, 2002a; Pawlowski et al., 2000; Sunder, 2006). For traditional societies, on the other hand, the relationship between male height and mating success appears to be positive, but there is no evidence that male height significantly influences fertility or child survival (Kirchengast, 2000; Kirchengast and Winkler, 1995; Sear, 2006).

For women, a frequent finding has been a curvilinear relationship between height and reproductive success (Brush et al., 1983; Mitton, 1975; Mueller, 1979; Nettle, 2002b; Veta, 1975 *but* see Allal et al., 2004; Sear et al., 2004 for a linear trend). Both tall and short women appear to be disadvantaged in terms of fitness. For modern societies, there might even be a weak selection pressure towards shortness for women, because of reduced mating success amongst tall women (Nettle, 2002b). However, maternal height has been thought to have positive effects on outcomes of pregnancy. Maternal height is for example negatively related to difficulties during childbirth, as well as low birth weight of neonates (Kelly et al., 1996; Magadi et al., 2003; Mahmood et al., 1988; Prasad and Al-Taher, 2002). Taller women are also more likely to have twins (Basso et al., 2004; Reddy et al., 2005), indicating that they are able to invest more in their offspring. Archaeological and epidemiological evidence also suggests that, in general, height is negatively related to morbidity and mortality rates, not only in men but also in women (Gunnell et al., 2001; Kemkes-Grottenhaler, 2005; Silventoinen et al., 1999). For a sample of Gambian women, height was found to positively influence child survival rates, with taller women having higher overall reproductive success for this reason (Allal et al., 2004; Sear et al., 2004). This is despite taller women reproducing later. A study of Guatemalan women also found that shorter women have fewer surviving children (Martorell et al., 1981).

By contrast, one study of a sample of lower caste Indian women found negative effects of height on reproductive success, with taller women having lower fertility and lower numbers of surviving children (Devi et al., 1985). Some studies have also failed to find any relation at all between maternal height and reproductive success (Bailey and Garn, 1979; Kirchengast, 2000; Lasker and Thomas, 1976).

Thus, for women the findings of the relationship between height and reproductive success are mixed. It appears that the relationship between female height and reproductive success might be modified by environmental factors. In an environment with few resources, height might be a reflection of health status to a greater extent than is true for an affluent population (Sear et al., 2004; Silventoinen, 2003). In particular, where infant mortality is high, the positive relationship between maternal height and child survival may outweigh the later reproduction of tall women. Here, we examine the impact of women's height on reproductive success for a stressed population in rural Guatemala. We investigate whether the relationship between height and reproductive success is linear or curvilinear while controlling for educational attainment, ethnicity, and age.

METHODOLOGY

For our analysis we used the Encuesta Guatemalteca de Salud Familiar of 1995 (EGSF). This is a cross-sectional study that collected data from 2,872 women between 18- and 35-years-old in rural Guatemala on a wide variety of economic, anthropometric, and sociodemographic variables. Data were collected in 1995 and participation rate in this survey was 89% (Peterson et al., 1997).

Contract grant sponsor: National Institutes of Child Health and Human Development.

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Received 17 January 2007; Revision received 10 May 2007; Accepted 15 May 2007

DOI 10.1002/ajhb.20708

Published online in Wiley InterScience (www.interscience.wiley.com).

TABLE 1. Descriptive statistics (frequencies or means ± one standard deviation) for the analyses

	Ever given birth (yes: 1994; no: 577) ($n = 2{,}571$)	Ever had stillbirth (yes: 153; no: 1867) ($n = 2{,}020$)	Age at first birth 19.17 (±3.11) ($n = 1{,}975$)
Height	147.19 (±5.76) cm	147.02 (±5.69) cm	147.06 (±5.67) cm
Attained grades	2.22 (±2.14) years	2.03 (±2.98) years	1.99 (±2.08) years
Indigenous	$n = 1{,}614$	$n = 1{,}280$	$n = 1{,}255$
Ladina	$n = 957$	$n = 740$	$n = 720$
Age	25.78 (±5.19) years	26.86 (±4.92) years	26.94 (±4.9) years
	Ever born children 3.56 (±2.03) ($n = 1{,}989$)	Survival ratio 0.92 (±0.17) ($n = 1{,}989$)	Death of first child (yes: 232; no: 1758) ($n = 1{,}989$)
Height	147.03 (±5.67) cm	147.03 (±5.67) cm	147.03 (±5.67) cm
Attained grades	1.97 (±2.07) years	1.97 (±2.07) years	1.97 (±2.07) years
Indigenous	$n = 1{,}267$	$n = 1{,}267$	$n = 1{,}267$
Ladina	$n = 722$	n= 722	$n = 722$
Age	26.95 (±4.89) years	26.95 (±4.89) years	26.95 (±4.89) years

The Guatemalan population is strongly socially divided into two ethnic groups of more or less equal size (Glei et al., 2003; Goldman and Glei, 2003). Only a fraction of the population, about 2% of the sample, does not identify themselves as being part of either group. The indigenous population consists of descendants of the Mayan and other preconquest populations, of which some only speak Mayan. The Ladina group is Spanish speaking and are of both preconquest population and European descent. The indigenous group is more socially excluded and poorer than the Ladina group. While the Ladina group can be found in all social strata of society, the indigenous group predominantly occupies the lowest social stratum.

Guatemala was among the poorest countries in Latin America and the world at the time of the survey and this still remains the case (Edwards, 2002; Gragnolati and Marini, 2006; Steele, 1994). The majority of the population did not have appropriate access to affordable public health, sanitation, potable water, and electricity at the time of the survey (Goldman and Glei, 2003; Peterson et al., 1997). The average household income was ~29 US$ a month at the time of the survey. Compared to other countries in Latin America, infant and maternal mortality in Guatemala is high (49 per 1,000 and 190 per 1,000, respectively; World Bank, 1999 in Goldman and Glei, 2003; for 2004: infant mortality is 45 per 1,000; Word Health Organization, 2006). Guatemala, especially the rural areas, is only just beginning the demographic and epidemiological transition (Goldman et al., 2001; Gragnolati and Marini 2006). The total fertility rate has dropped from 5.8 in 1990 to 3.82 in 2006 (CIA, 2006; UNPD, 2005). The demographics of this rural population are thus useful to study reproductive patterns of a population under stress from a Darwinian perspective. This sample has been widely used for the study of provision health care (Glei et al., 2003; Goldman and Glei, 2003) and beliefs about illness (Goldman et al., 2001; Heuveline and Goldman, 2000). Additional information on the sample can be found in the codebook or in these previously published articles.

We excluded participants for which data on the variables were missing, after which 2,571 participants were retained for the analysis. The descriptive statistics for the variables are summarized in Table 1. We present the raw data by use of height deciles (derived from $n = 2{,}571$).

For each of our analyses we controlled for the effects of age, ethnicity, and attained level of education. Attained level of education is coded as an interval variable, which is the sum of the grades completed. Age is coded as age of last birthday, and is thus an approximation. Besides fitting height (cm), we also included squared height (cm^2) and ln(height) as additional variables to test for possible curvilinear effects in each analysis.

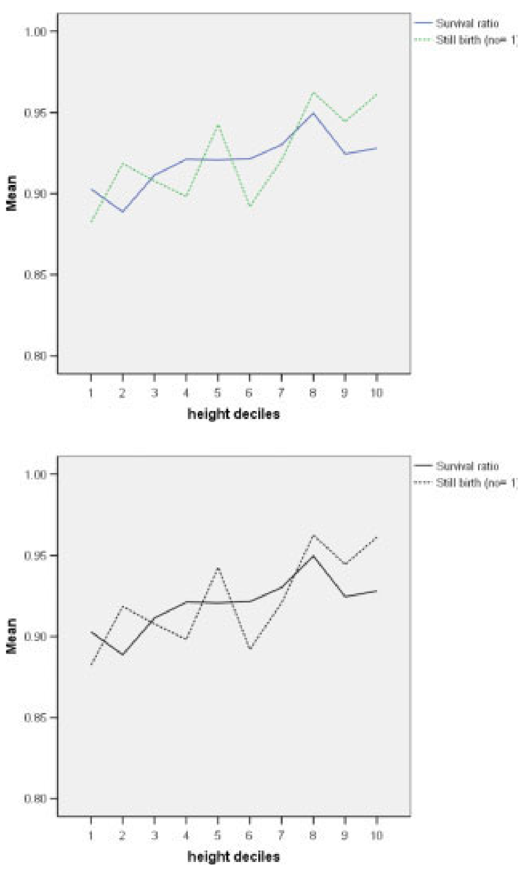


Fig. 1. Line graph of mean survival ratio and occurrence of a stillbirth by height deciles. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Binomial logistic regression was first used to analyze the likelihood of "never given birth" and the likelihood of having had a stillbirth (Hosmer and Lemeshow, 1989;

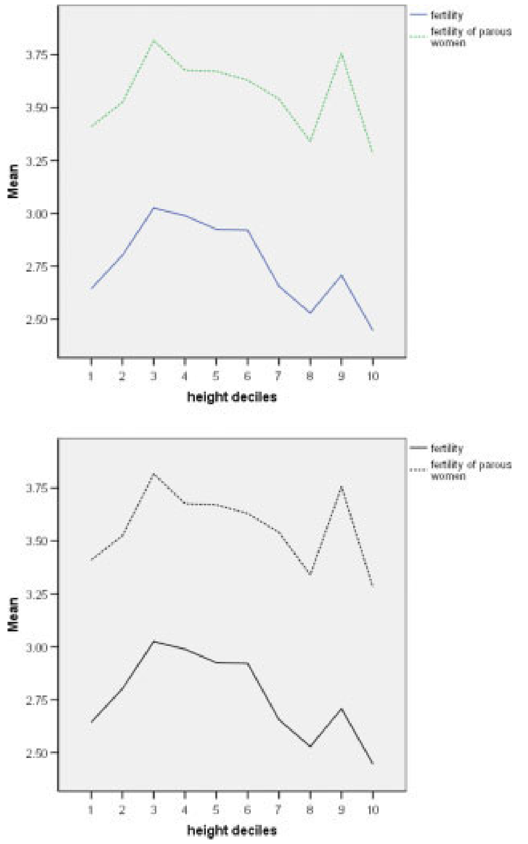


Fig. 2. Line graph displaying mean fertility and fertility for parous women by height deciles. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

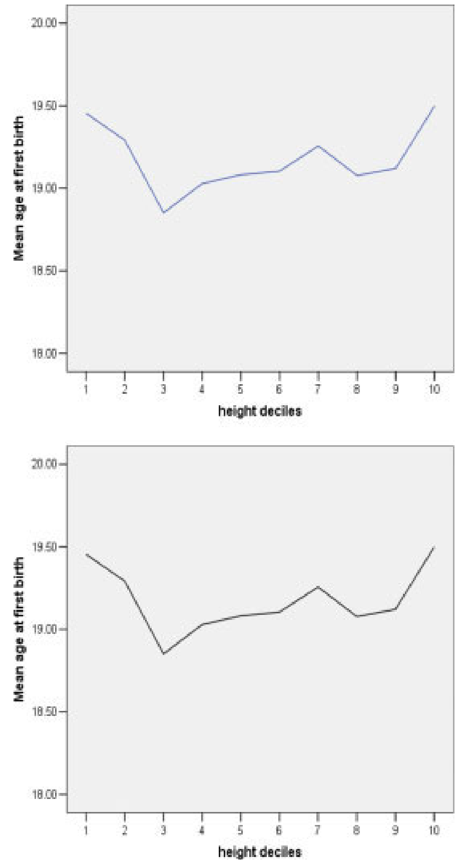


Fig. 3. Line graph of mean age at first birth by height deciles. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley. com.]

Menard, 1995; Pampel, 2000). Binomial logistic regression as statistical technique is relatively free of assumptions and statistically robust. Unlike ordinary least square regression (OLS) parameters are estimated by maximum likelihood. As a parameter selection procedure we used backward stepwise. Model outcomes were only marginally different in terms of model fit and Nagelkerke R^2 (Nagelkerke, 1991) when forward stepwise was used instead. Here, we will report the likelihood ratio tests for variables (p_{llr}) in the model and the parameter estimates for the models (see Peng et al., 2002). Given that these are dichotomous data, binomial logistic regression is a preferred technique over general linear mixed models (GLMM's) which requires the dependent to be interval.

We also built General Linear Mixed Models with age, age^2, height, squared height (cm^2), ln(height), ethnicity, and attained level of education as predictors for age at first birth, fertility (number of live births) of parous women, and survival ratio (number of living children/ number of ever born children at time of survey). The models had absolute parameter and loglikelihood convergence and parameters were estimated by Restricted Maximum Likelihood (SPSS, 2005; see Verbeke and Molenberghs, 2000). We first examined baseline models with no random effects, then we constructed models with a random intercept and subsequently models with random intercepts and random slopes. We used an unstructured covariance matrix for the random effects (Litell et al., 2000). On the basis of Schwarz's Bayesian information criterion (BIC) (smaller-is-better; we also examined AIC: see, Kuha, 2004), we selected the final model. This model could be a baseline model without random effects, have a random intercept or have a random intercept and random slope(s). Only significant parameters were retained for the final model (based on F-test). We will present the BIC of the final model, and parameter estimates.

We also performed stepwise Cox regression to examine the independent effect of height on the likelihood of the firstborn child's death, while controlling for other variables. As a parameter selection we used backward stepwise (likelihood ratio), and the parameters included were ethnicity, age, age^2, height, height^2, ln(height), and attained level of education.

There is little indication that multicollinearity confounds any of the analyses. For our models we will focus on the effects of height, and not discuss the effects of control variables.

RESULTS

Descriptive statistics

From Figure 1 it appears that taller women are less likely to experience stillbirth. Taller women also have higher survival ratios. Figure 2 shows a curvilinear trend as well, with both extremely short and very tall women having lower fertility. Figure 3 shows a curvilinear trend

TABLE 2. Odds ratios (exp(λ)) for logistic regression and unstandardized parameter estimates for GLMM's

Dependent	Never gave birth	Stillbirth (yes)	Age at first birth	Fertility	Survival ratio
Analysis	Logistic	Logistic	GLMM	GLMM	GLMM
Nagelkerke R^2/BIC	$R^2 = 0.33$	$R^2 = 0.05$	BIC = 10137.29	BIC = 7371.67	BIC = −1378.79
Intercept			91.47	−208.318	−0.17
Height	ns	ns	−1.092**	ns	ns
Height^2	ns	0.9998***	0.004**	0.001**	ns
Ln(height)	ns	ns	ns	45.646**	0.225*
Age	0.375***	1.077***	0.541***	0.258***	−0.002*
Age^2	1.015***	ns	−0.007*	ns	ns
Education	1.252***	0.893*	0.334***	−0.168***	0.005**
Indigenous → Ladina	ns	1.66**	ns	ns	ns

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

where both extremely tall and extremely short women have a delayed first birth.

Likelihood of childlessness (never gave birth)

The model for never have given birth has a Nagelkerke R^2 of 0.33 (model fit: −2Loglikelihood (−2LL) = 2057.74; χ^2= 560.17; P < 0.0001; Table 2). There is no effect of height, height^2, or ln(height) on the likelihood of never have given birth (χ^2-test: respectively: $P < 0.3$; $P < 0.25$; $P < 0.3$). Height does not affect the likelihood of childlessness, whereas age and age^2 do. Odds ratios can be interpreted as follows: an increase of the number attained grades by one grade makes it 1.18 times more likely that the respondent has never given birth (versus given birth).

Likelihood of a stillbirth

The model for likelihood of having had a stillbirth has a Nagelkerke R^2 of 0.056 (model fit: −2LL= 1010.29; χ^2= 47.66; P < 0.0001). Squared height proved a significant predictor of never having had a stillbirth, whereas height and ln(height) did not improve the model (χ^2 test; P > 0.25). Extremely short women are thus at risk of having had a stillbirth. While controlling for other variables we find that for each squared cm, it becomes 0.9998 times more likely that the woman has not had a stillbirth.

Age at first birth

The model with best fit was a baseline model, i.e. had no random slopes or random intercept (BIC= 9891.78). The model allows us to predict the age at first birth using the equation of the model: predicted age of first birth = 91.47 – 1.092*(height) + 0.004*(height^2) + 0.334*(education) + 0.541*(age) – 0.007*(age^2). Women of average stature (147.06 cm), age (26.95 years), and educational attainment (1.97 years) are predicted to have their first child when they are 19.22 years. While extremely short (2 stds. below average height: 135.72 cm) women of the same level of education are predicted to have their first child at 20.02 years. On the other hand, extremely tall women (2 stds. above average height: 158.4 cm) of the same level of education are predicted to have their first child at 19.35 years.

Fertility (number of live births)

The model with the lowest BIC, only has baseline effects and no random intercept or random effects for variables (BIC: −7371.67). The equation can be written as: predicted number of children = −208.318 + 45.646*ln(height) – 0.001*(height^2) + 0.258 *age – 0.168*(education).

TABLE 3. Parameter estimates (λ) and odds ratios (exp(λ)) for Cox regression on survival of firstborn

Survival of firstborn	Parameter estimate	Odds ratios
Height	0.884*	2.42*
Height^2	ns	ns
Ln(height)	−132.361*	$3.28 \times e^{-58}$*
Age	−0.326***	0.721***
Age^2	ns	ns
Education	ns	ns
Indigenous → Ladina	ns	ns

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Women of average height (147.03 cm), age (26.94 years), and educational level (1.97 years) are predicted to have 3.49 children. Extremely short women (135.69 cm) of the same age and educational attainment, however, are predicted to have 3.18 children. Extremely tall women (158.37 cm), of the same age and educational attainment are predicted to have 3.26 children.

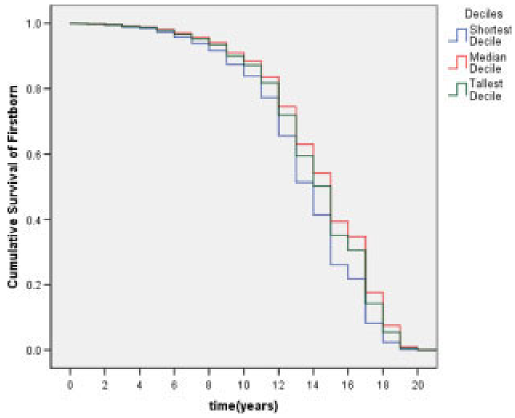
Survival ratio (number of living children/number of ever born children)

The model with the lowest BIC, only has baseline effects and no random intercept or random effects for variables (BIC: −1378.97). Inclusion of linear height of squared height did not significantly improve the prediction of the survival ratio (t-test; both P > 0.2). Extremely short women (135.69 cm) of average age (26.94 years) and educational level (1.97 years) are predicted to have a survival ratio of 0.9, whereas, women of average height (147.03 cm) and extremely tall women (158.37 cm) of similar age and educational attainment have higher survival ratios for their offspring (0.936 and 0.918 respectively). Extremely short women thus have worse survival ratios for their children than taller women.

Likelihood of death for first child

Survival analysis by Cox regression shows an effect of linear height, ln(height), and age on survival of the firstborn child (final model: −2LL= 2709.32; χ^2= 236.72; P < 0.0001; Table 3). Given that we have a curvilinear effect and linear effect for height with different parameters, the effect of height can be more easily observed when comparing survival curves for different heights (Fig. 4).

When comparing the survival curves for the median decile and for extreme heights (shortest decile and tallest decile), extremely short women show poorer child survival than for women who are extremely tall (Fig. 4). There



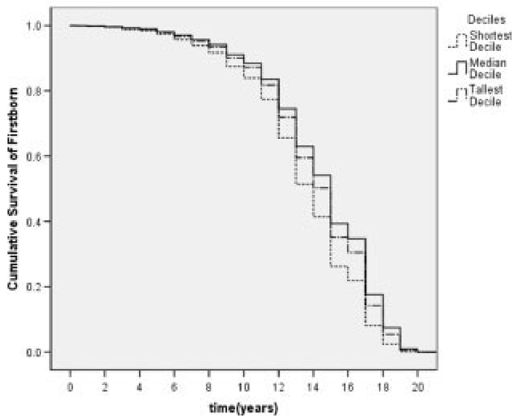


Fig. 4. Cumulative survival function for firstborn based on Cox regression for women of shortest decile (<140.1 cm), median decile (Decile 5; 145.6 cm < × < 147.1 cm), tallest decile (>154.8 cm). Age of the women is set to the mean. Note that there are no children older than 20 in the sample. Therefore all children aged 20 or above have a fixed cumulative survival of 0. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

appears to be a ceiling effect for height, as women of extreme height show lower survival than women of average height.

DISCUSSION

Squared height was a significant predictor of the likelihood of having a stillbirth indicating that short women are at risk. Yet, above a certain threshold, increases in height do not proportionally decrease the risk of a stillbirth. While the complications of short stature during childbirth are well-documented (Kelly et al., 1996; Magadi et al., 2003; Mahmood et al., 1988; Prasad and Al-Taher, 2002), the threshold effect of extreme tallness or any drawbacks thereof during childbirth has not been documented to our knowledge.

There is no indication of a relationship between height and childlessness (never have given birth). Extremely short and extremely tall women, however, have fewer children and have poorer survival rates of their children than women of average height. However, when comparing extremely tall women and extremely short women in terms of fertility and survival rates, extremely short women are worse off than extremely tall women. The finding that, in general, taller women have better survival rates (survival ratio and cumulative survival of firstborn) for their children than shorter women is in line with previous findings for Gambia (Allal et al., 2004; Sear et al., 2004) and Guatemala in the 1970's (Martorell et al., 1981). However, unlike Sear et al. (2004) who found no effect of height on fertility, in these data, height significantly influences fertility as well as child survival. Height also influences age at first birth. Both extremely tall and short women started to reproduce later than women of average height, although this lag is very small. This result thus points to the documented trade-off between somatic and reproductive effort (Sear et al. 2004). However, the trade-off between growing tall and reproductive output appears less clear-cut for this population than for the Gambian population.

It is possible that some of the women were still growing as the sample included women between 18- and 35-years-old. It is commonly assumed that growth stops around 3 years after the age of first age menarche (Martorell et al., 1994). For rural Guatemala, mean age at first menarche is estimated at 13.1 years (±1.3 years) (Awal et al., 1996). Given that mean age at first birth is 19.1 years (±3.1 years), the fact that some women would not have stopped growing would only confound the analyses for a fraction of the women. Moreover, our analyses by GLMM take this possibility into account as we also examined models with random effects for age and height.

In a stressed environment, such as under poverty, height thus appears to be a reliable indicator of maternal ability to reproduce successfully. In general, the relationship between height and reproductive success for this sample appears to be curvilinear, with both extremely tall and extremely short women having lower reproductive success than women of average height. However, the penalties affecting very short women are generally greater than those affecting very tall women. We suggest a role for environmental mediators of the relationship between height and reproductive success, such as environmental stress. In an environment where stress is high, for instance due to scarcity of resources, growing tall is an accurate indication of health status, and will positively relate to female reproductive success, in particular through increased infant survival. In affluent populations, height is not so strongly related to health, infant survival is uniformly high, and female fitness is determined by other factors such as male mate preferences. This explains the difference in findings between this study and the Gambian one (Sear et al., 2004) on the one hand, and the studies from Western populations on the other (Nettle, 2002b).

CONCLUSION

In a stressed environment, female height shows curvilinear effects on reproductive success, with extremely short and extremely tall women having lower reproductive success overall than women of average height. However, extremely short women are (far) worse off in fitness terms than extremely tall women, so the average effect of increasing height on fitness is positive.

ACKNOWLEDGMENT

The authors thank RAND and the ICSPR consortium who made the EGSF publicly available. The EGSF data were collected by Noreen Goldman (Princeton University) and Anne Pebley (RAND) in collaboration with the Nutritional Institute of Central America and Panama (INCAP).

Authors also thank the reviewers for comments which substantially improved previous drafts.

LITERATURE CITED

Allal N, Sear R, Prentice A, Mace R. 2004. An evolutionary analysis of stature, age at first birth and reproductive success in Gambian women. Proc Roy Soc Lond [Biol] 271:465–470.

Awal DK, Schroeder DK, Martorell R, Haas JD, Rivera J. 1996. Early childhood determinants of age at menarche in rural Guatemala. Am J Hum Biol 8:717–723.

Bailey SM, Garn SM. 1979. Socio-economic interactions with physique and fertility. Hum Biol 51:317–333.

Basso O, Nohr EA, Christensen K, Olson J. 2004. Risk of twinning as a function of height and body mass index. JAMA 291:1564–1566.

Bielicki T, Szklarska A. 1999. The stratifying force of family size, urbanization and parental education in socialist-era Poland. J Biosocial Sci 31:525–536.

Brush G, Boyce AJ, Harrison GA. 1983. Associations between anthropometric variables and reproductive performance in a Papua New Guinea highland population. Ann Hum Biol 10:223–234.

CIA. 2006. CIA World Fact Book. Washington: CIA.

Devi MR, Kumari JR, Srikumari CR. 1985. Fertility and mortality differences in relation to maternal body size. Ann Hum Biol 12:479–484.

Edwards J. 2002. Education and poverty in Guatemala. Technical Paper No. 3. Washington, D.C.: The World Bank.

Glei DA, Goldman N, Rodriguez G. 2003. Utilization of care during pregnancy in rural Guatemala. Soc Sci Med 57:2447–2463.

Goldman N, Glei DA. 2003. Evaluation of midwifery care: Results from a survey in rural Guatemala. Soc Sci Med 56:685–700.

Goldman N, Pebley AR, Beckett M. 2001. Diffusion of ideas about personal hygiene and contamination in poor countries: evidence from Guatemala. Soc Sci Med 52:53–69.

Gragnolati M, Marini A. 2006. Health and Poverty in Guatemala. Technical Paper No. 5, World Bank working paper (36206).

Gunnell D, Rogers J, Dieppe P. 2001. Height and health: predicting longevity from bone length in archaeological remains. J Epidemiol Commun H 55:505–507.

Heuveline P, Goldman N. 2000. A description of child illness and treatment behavior in Guatemala. Soc Sci Med 50:345–364.

Hosmer D, Lemeshow S. 1989. Applied logistic regression. New York: Wiley.

Kelly A, Kevany J, de Onis M, Shah PM. 1996. A WHO Collaborative study of maternal anthropometry and pregnancy outcomes. Int J of Gynecol Obstet 53:219–233.

Kemkes-Grottenthaler A. 2005. The short die young: The interrelationship between stature and longevity—evidence from skeletal remains. Am J Phys Anthropol 128:340–347.

Kirchengast S. 2000. Differential reproductive success and body size in !Kung San people from northern Namibia. Collegium Anthropol 24:121–132.

Kirchengast S, Winkler EM. 1995. Differential reproductive success and body dimensions in Kavango males from urban and rural areas in northern Namibia. Hum Biol 67:291–309.

Kuh DJL, Wadsworth MEJ. 1993. Physical health status at 36 years in a British national birth cohort. Soc Sci Med 37:905–916.

Kuha J. 2004. AIC and BIC: Comparisons of Assumptions and Performance. Sociol Method Res 33:188–229.

Litell SC, Pendergast J, Natarajan R. 2000. Modelling covariance structure in the analysis of repeated measures data. Stat Med 19:1793–1819.

Lasker GW, Thomas R. 1976. Relationship between reproductive fitness and anthropometric dimensions in a Mexican Population. Hum Biol 48:775–791.

Macintyre S, West P. 1991. Social, developmental and health correlates of 'attractiveness' in adolescence. Sociol Health Ill 13:149–166.

Magadi M, Agwanda A, Obare F, Taffa N. 2003. Comparing maternal health indicators between teenagers and older women in sub-Saharan Africa: evidence from DHS. Southampton, UK: Southampton Statistical Sciences Research Institute. (S3RI Applications and Policy Working Papers, A03/18). Available at http://eprints.soton. ac.uk/8152/.

Magnusson PKE, Rasmussen F, Gyllensten UB. 2006. Height at age 18 years is a strong predictor of attained education later in life: cohort study of over 950 000 Swedish men. Int J Epidemiol 35:658–663.

Mahmood TA, Campbell DM, Wilson AW. 1988. Maternal height, shoe size and outcome of labour in white primigravidas: a prospective anthropometric study. BMJ 297:515–517.

Martorell R, Delgado HL, Valverde V, Klein RE. 1981. Maternal stature, fertility and infant mortality. Hum Biol 53:303–312.

Martorell R, Khan LK, Schroeder DG. 1994. Reversibility of stunting: Epidemiological findings in children from developing countries. Eur J Clin Nutr 48:S45–S47.

Mascie-Taylor CGN, Lasker GW. 2005. Biosocial correlates of stature in a British national cohort. J Biosocial Sci 37:245–251.

Menard S. 1995. Applied logistic analysis, quantitative applications in the social sciences series No. 106. Thousand Oaks: Sage Publications.

Mitton JB. 1975. Fertility differentials in modern societies resulting in normalizing selection for height. Hum Biol 49:189–200.

Mueller WH. 1979. Fertility and physique in a malnourished population. Hum Biol 51:53–166.

Mueller U, Mazur A. 2001. Evidence of unconstrained directional selection for male tallness. Behav Ecol Sociobiol 50:302–311.

Nagelkerke NJD. 1991. A note on a general definition of the coefficient of determination. Biometrika 78:691–692.

Nettle D. 2002a. Height and reproductive success in a cohort of British men. Hum Nat 13:473–491.

Nettle D. 2002b. Women's height, reproductive success and the evolution of sexual dimorphism in modern humans. Proc Roy Soc Lond [Biol] 269:1919–1923.

Pampel FC 2000. Logistic regression: a primer, quantitative applications in the social sciences series No. 132. Thousand Oaks, Sage Publications.

Pawlowski B, Dunbar RIM, Lipowicz A. 2000. Evolutionary fitness: tall men have more reproductive success. Nature 403:156.

Peng C-YJ, Lee KL, Ingersoll G. 2002. An introduction to logistic regression analysis and reporting. J Educ Res 96:1–14.

Peterson C, Goldman N, Pebley AR. 1997. The 1995 Guatemalan Survey of Family Health (EGSF): overview and codebook. Santa Monica, CA: RAND.

Prasad M, Al-Taher H. 2002. Maternal height and labour outcome. J Obstet Gynaecol 22:513–515.

Reddy U, Branum AM, Klebanoff MA. 2005. Relationship of maternal body-mass index and height to twinning. Obstet Gynecol 105:593–597.

Sear R. 2006. Height and reproductive success: how a Gambian population compares to the West. Hum Nat 17:405–418.

Sear R, Allal N, Mace R. 2004. Height, marriage and reproductive success in Gambian women. Res Econ Anthropol 23:203–224.

Silventoinen K. 2003. Determinants of variation in adult body height. J Biosocial Sci 35:263–285.

Silventoinen K, Lahelma E, Rahkonen O. 1999. Social background, adult body-height and health. Int J Epidemiol 28:911–918.

SPSS 2005. Linear Mixed-Effects Modeling in SPSS: an introduction to the MIXED Procedure. Chicago: SPSS Inc.

Steele D. 1994. Guatemala. In: Psacharopoulos G, Patrinos HA, editors. Indigenous people and poverty in Latin America: an empirical analysis. Washington, DC: World Bank. p 105–140.

Sunder M. 2006. Physical stature and intelligence as predictors of the timing of baby boomers very first date. J Biosocial Sci 38:821–833.

Szklarska A, Koziel S, Bielecki T, Malina RM. 2007. Influence of height on educational attainment in males at 19 year of age. J Biosocial Sci 35:575–582.

Teasdale TW, Owen DR, Sorensen TI. 1991. Intelligence and educational level in adult males at the extremes of stature. Hum Biol 63:19–30.

World Health Organization. 2006. Working together for health: The world health report. Available at http://www.who.int/whr/2006/whr06_en.pdf.

UNPD 2005. World Population Prospects: The 2004 Revision. New York: UN.

Verbeke G, Molenberghs G. 2001. Linear mixed models for longitudinal data. New York: Springer.

Vetta A. 1975. Fertility, physique and intensity of selection. Hum Biol 47:283–293.