Sex Ratio at Birth and Mortality Rates Are Negatively Related in Humans

Madhukar Shivajirao Dama*
Rural Veterinary Dispensary, Rajola, Bidar, India

Abstract

Evolutionary theory posits that resource availability and parental investment ability could signal offspring sex selection, in order to maximize reproductive returns. Non-human studies have provided evidence for this phenomenon, and maternal condition around the time of conception has been identified as most important factor that influence offspring sex selection. However, studies on humans have reported inconsistent results, mostly due to use of disparate measures as indicators of maternal condition. In the present study, the cross-cultural differences in human natal sex ratio were analyzed with respect to indirect measures of condition namely, life expectancy and mortality rate. Multiple regression modeling suggested that mortality rates have distinct predictive power independent of cross-cultural differences in fertility, wealth and latitude that were earlier shown to predict sex ratio at birth. These findings suggest that sex ratio variation in humans may relate to differences in parental and environmental conditions.

Citation: Dama MS (2011) Sex Ratio at Birth and Mortality Rates Are Negatively Related in Humans. PLoS ONE 6(8): e23792. doi:10.1371/journal.pone.0023792
Editor: Rebecca Sear, Durham University, United Kingdom
Received December 22, 2010; Accepted July 26, 2011; Published August 24, 2011
Copyright: © 2011 Madhukar Shivajirao Dama. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
Funding: The author has no support or funding to report.
Competing Interests: The author has declared that no competing interests exist.
* E-mail: madhukar262@gmail.com

Introduction

“I formerly thought that when a tendency to produce the two sexes in equal numbers was advantageous to the species, it would follow from natural selection, but I now see that the whole problem is so intricate that it is safer to leave its solution for the future.”
Charles Darwin, in Descent of Man, 1874.

Trivers and Willard predicted that, in polygynous mating systems, mothers in good condition could increase reproductive success by biasing investment in sons [1]. Superior quality sons can leave many more offspring than daughters can. Hence, where the fitness gains of offspring quality are sex-specific, a female with ability to produce high-quality offspring could be expected to produce more sons and vice-versa. Empirical evidence for biased offspring sex ratios gathered from many taxa support this theory (reviewed in [2,3]). Trivers and Willard hypothesis hold true for species that produce small litters and depends on 3 assumptions: 1) that the offspring condition at the end of parental investment is correlated with the condition of the dam; 2) that the differences in offspring condition at the end of parental investment are carried over to adulthood; and 3) that the adult will be differentially advantaged in reproductive success through slight advantages in condition.

Meta-analysis of non-human studies has suggested that sex ratio adjustments are most likely to occur around the time of conception. This adjustment was strongly correlated with maternal condition around conception, such that mothers in good condition during this period produced more sons [4]. Similar findings have been reported in humans when maternal condition was considered in relation to sex ratio adjustment [5,6,7,8,9,10], however some studies have reported inconsistent findings [11,12]. Further, steady decline of natal sex ratio in some countries was linked to deterioration of health due to increased exposure to environmental toxins during recent decades [13].

Average national sex ratio at birth (SRB) in humans is slightly male biased (105 males per 100 males), with remarkable deviation for some countries [14]. Systematic deviations from this ratio occurs in conditions such as economic and natural catastrophes [15,16], war [17,18,19,20], chronic stress [20], etc. Demographic factors like ethnicity [21], parental age [22,23], mother’s weight [7], birth-order [24], smoking [25], certain disease conditions [26,27], certain professions [28], exposure to environmental toxins [29], seasonality of birth [30], etc are also linked to sex ratio adjustments. These studies have shown that higher birth-order, older parental age, low or high maternal weight, exposure to toxins and stressful events lower the chances of male births, leading to decreased SRB. While physiological basis for influence of external factors on SRB is not understood, sex hormone level alterations [31,32,33] and differential survival during embryogenesis [34,35] are proposed as likely mediators.

Although, well corroborated by non-human studies, TWH still lacks support for human populations, even after identification of staggering number of factors. This is due to studies reporting conflicting results [36,37,38,39,40,41,42,43], which could be attributed to the use of disparate factors like parental social status, education level, environmental calamities, resource availability, etc as measures of parental investment ability instead of lineal measures of physical condition around the time of conception [36].

Physical health and environmental conditions are directly reflected in life expectancy, the duration an individual presumes they have left to live, with those living under economic constraints, diseased state and unstable environments expecting to die sooner.
Methods explained by cross-national differences in mortality rates. Conducted to examine whether global SRB variation could be more likely to have a male birth than women who thought they would live shorter [51]. In light of the above, present study was finding that women who believed they had longer to live were more likely to have a male birth than women who thought they would live shorter [51]. In light of the above, present study was conducted to examine whether global SRB variation could be explained by cross-national differences in mortality rates.

Methods

Dependent variable

Counts of the sex ratio at birth for the year 2009 were taken from the Central Intelligence Agency, World Factbook [63]. Sex ratio at birth is conventionally reported as the number of males per 100 females, and this convention is employed here (mean = 105.0, median = 105.0, s.d = 2.0). Afghanistan, Bangladesh, China, India, Iran, South Korea, Pakistan, and Taiwan were excluded from the analysis owing to prevalence of son-preference and extensive practice of medical termination of female fetuses (Hesketh & Xing 2006).

Independent variables

As a measure of mortality level for each nation, life expectancy at birth (2008, mean = 68.5, median = 71.9, s.d = 10.4) and healthy life expectancy (HALE; 2007, mean = 60.0, median = 62.0, s.d = 9.9) were used [64]. While, life expectancy at birth summarizes the mortality pattern that prevails across all age groups, healthy life expectancy (HALE) at birth adds up expectation of life for different health states and measures average number of years that a person can expect to live in “full health” by taking into account years lived in less than full health due to disease and/or injury. These two measures reflect age-standardized summary of mortality in a population, however mortality rates at different stages of life were also studied to identify if any of these have stronger correlation with SRB. Infant mortality rate (IMR, 2009, mean = 33.5, median = 19.0, s.d = 32.8), under-five mortality rate (U5MR, 2009, mean = 40.3, median = 22.0, s.d = 54.6), maternal mortality ratio (MMR, 2000, mean = 199.2, median = 65.0, s.d = 273.44) and adult mortality rate (AMR, 2008, mean = 211.2, median = 167.0, s.d = 132.3) were taken from WHO [64]. While IMR and MMR are actual number of deaths of infant (during the first year of life per 1000 live births in a given year) and mothers (per 100000 live births in a given year), U5MR and AMR are the probabilities of dying before reaching the age of five and between the age of 15 to 65 respectively. All the four variables were log transformed for normality.

Control variables

Fertility and sex ratio at birth are negatively correlated in human populations [52]. Fertility values (2008) were taken from World Bank [65]. Total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with current age-specific fertility rates (mean = 2.9, median = 2.4, s.d = 1.5). Wealth and sex ratio at birth are positively correlated in humans [53]. Gross domestic product per capita based on purchasing power parity (GDP, 2009) is used as a measure of wealth. GDP data was taken from the World Factbook [63]. Values were log transformed for normality (mean = 3.7, median = 3.6, s.d = 0.7). Latitude, which represents the angular distance of a location south or north of the equator and sex ratio at birth are positively correlated in human populations [54]. Latitude values for nations were obtained from the World Factbook [63] and numerical values were used irrespective of direction (mean = 25.9, median = 22.0, s.d = 17.2).

Statistical analysis

The relationship between life expectancy and sex ratio at birth was studied using regression model. Sex ratio at birth was entered as dependent variable and life expectancy was entered as independent variable. Each regression model included latitude, fertility rate and wealth as control variables. For variables showing high collinearity (square root of variance inflation factor greater than 2.0), ridge regression model was employed [55]. Ridge regression artificially reduces correlation coefficient of each pair of variables by

| Table 1. Correlation among the primary variables in the study: sex ratio at birth, life expectancy at birth, healthy life expectancy, adult mortality rate, infant mortality rate, under 5 mortality rate and maternal mortality ratio. |
|----------------------------------------|
| 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|---|---|---|---|---|---|---|---|---|---|
| Sex ratio at birth | 1   | .679** | .669** | –.627** | –.629** | –.626** | –.639** | .694** | .516** | –.642** |
| Life expectancy at birth | 1   | .980** | –.934** | –.816** | –.898** | –.914** | .529** | .801** | –.824** |
| Healthy life expectancy | 1   | –.929** | –.823** | –.894** | –.915** | .571** | .844** | –.831** |
| Adult mortality rate | 1   | .769** | .780** | .799** | –.427** | –.720** | .690** |
| Maternal mortality ratio | 1   | .827** | .827** | –.526** | –.713** | .767** |
| Under 5 mortality rate | 1   | .988** | –.545** | –.751** | .895** |
| Infant mortality rate | 1   | –.574** | –.792** | .890** |
| Latitude | 1   | .578** | –.601** |
| GDP | 1   | –.748** |

**p < 0.01.
Correlations are Pearson’s r, n = 167.
<https://doi.org/10.1371/journal.pone.0023792.t001>
incorporating a ridge parameter to the diagonal of a correlation matrix of highly collinear independent variables, leading to reduced error variance of estimators. Based on this principle, ridge regression overcomes the collinearity problem [56]. Continent of origin was used as a nested variable in each model to make the sex ratio data for each nation an independent datapoint and control for continental variation that may influence sex ratio trends. Eight outliers were identified (i.e., Albania, Azerbaijan, Barbados, Table 2. Multiple regression analysis predicting sex ratio at birth by life expectancy at birth (1), healthy life expectancy (2), adult mortality rate (3), infant mortality rate (4), under 5 mortality rate (5) and maternal mortality ratio (6), after controlling for fertility, wealth and latitude (n = 159).

|   | $\beta$ (± s.e.) | t     | p     |
|---|-----------------|-------|-------|
| 1 | Intercept       | 100.969 | 0.000 |
|   | Latitude        | 0.169 (0.070) | 2.415 | 0.017 |
|   | GDP             | -0.086 (0.087) | -0.980 | 0.329 |
|   | Fertility       | -0.223 (0.093) | -2.415 | 0.017 |
|   | Continent       | 0.053 (0.067) | 0.783  | 0.435 |
|   | Life expectancy at birth | 0.402 (0.099) | 4.057  | 0.000 |
| R² = .48, adjusted R² = .46 | F(5,153) = 27.86, p < .00001 | |
| 2 | Intercept       | 106.936 | 0.000 |
|   | Latitude        | 0.155 (0.071) | 2.192 | 0.030 |
|   | GDP             | -0.101 (0.092) | -1.096 | 0.275 |
|   | Fertility       | -0.248 (0.092) | -2.690 | 0.008 |
|   | Continent       | 0.053 (0.069) | 0.775  | 0.440 |
|   | healthy life expectancy | 0.389 (0.107) | 3.621  | 0.000 |
| R² = .47, adjusted R² = .45 | F(5,153) = 26.70, p < .00001 | |
| 3 | Intercept       | 58.277  | 0.000 |
|   | Latitude        | 0.188 (0.071) | 2.472 | 0.015 |
|   | GDP             | -0.246 (0.002) | -2.184 | 0.030 |
|   | Fertility       | -0.387 (0.001) | -3.874 | 0.000 |
|   | Continent       | 0.073 (0.001) | 1.032  | 0.303 |
|   | Adult mortality rate | -0.406 (0.005) | -3.839 | 0.000 |
| R² = .50, adjusted R² = .49 | F(5,153) = 31.13, p < .00001 | |
| 4 | Intercept       | 98.130  | 0.000 |
|   | Latitude        | 0.120 (0.074) | 1.617 | 0.108 |
|   | GDP             | -0.112 (0.098) | -1.141 | 0.256 |
|   | Fertility       | -0.280 (0.091) | -3.058 | 0.003 |
|   | Continent       | 0.105 (0.066) | 1.592  | 0.113 |
|   | Infant mortality rate | -0.356 (0.112) | -3.171 | 0.002 |
| R² = .46, adjusted R² = .44 | F(5,153) = 25.65, p < .00001 | |
| 5 | Intercept       | 99.330  | 0.000 |
|   | Latitude        | 0.118 (0.074) | 1.599 | 0.112 |
|   | GDP             | -0.117 (0.096) | -1.216 | 0.226 |
|   | Fertility       | -0.251 (0.093) | -2.687 | 0.008 |
|   | Continent       | 0.096 (0.066) | 1.455  | 0.148 |
|   | Under 5 years mortality rate | -0.393 (0.116) | -3.388 | 0.001 |
| R² = .46, adjusted R² = .44 | F(5,153) = 26.14, p < .00001 | |
| 6 | Intercept       | 103.360 | 0.000 |
|   | Latitude        | 0.061 (0.075) | 0.807 | 0.421 |
|   | GDP             | -0.142 (0.092) | -1.538 | 0.126 |
|   | Fertility       | -0.244 (0.089) | -2.733 | 0.007 |
|   | Continent       | 0.106 (0.064) | 1.650  | 0.101 |
|   | Maternal mortality ratio | -0.473 (0.110) | -4.305 | 0.000 |
| R² = .48, adjusted R² = .47 | F(5,153) = 28.58, p < .00001 | |

Except (3), all are multiple ridge regression models at $\lambda = 0.1$, see methods for details.
doi:10.1371/journal.pone.0023792.t002
Armenia, Georgia, Grenada, Nigeria, and United States of America) that were preventing the data from confirming to the assumptions of regression model (identified based on large standardized residual values). However, all the regression models were also constructed for a second set of data that included these outliers. Before accepting the final model, the residuals were confirmed to be homoscedastic (Breusch-Pagan test, p > 0.05) and normally distributed (Ryan-Joiner’s test, p > 0.05). Statistical analyses were conducted using SPSS v. 16 and STATISTICA v. 10. Individual variables for all the nations are listed in table S1.

Results

Globally, natal sex ratios were positively correlated with life expectancy and healthy life expectancy (\( r = 0.68 \) and 0.67, both p < 0.001, table 1), demonstrating that significantly more sons are born in populations with superior life expectancy (LE: adjusted \( R^2 = 0.46, \beta = 0.69, p < 0.001 \), HALE: adjusted \( R^2 = 0.45, \beta = 0.67, p < 0.001 \)). This effect was linear: addition of polynomial function of these variables i.e. \( \text{LE}^2 \) or HALE\(^2\) (LE: \( \Delta R^2 = 0.001, p = 0.584 \), HALE: \( \Delta R^2 = 0.005, p = 0.237 \)) to the regression model did not change the \( R^2 \) value.

In separate multiple regression models, sex ratio was predicted using different mortality rates after controlling for latitude, fertility and GDP. Life expectancy at birth and HALE were significant positive predictors and IMR, MMR, U5MR and AMR were significant negative predictors of sex ratios (table 2 and figure 1). Similar results were obtained using data consisting of statistical outliers (table S2).

Discussion

The correlation between mortality indices and SRB was statistically significant at the national level worldwide. All the analysis showed that mortality rates were a significant predictors of sex ratios, whether using either individual mortality rates (IMR, MMR, U5MR and AMR) or averaged mortality indices (life expectancy and HALE). The zero-order correlation between life expectancy and sex ratio was higher than that of any other variable for which there is a previously proposed correlation (Table 1).

Multiple regression shows that, life expectancy and mortality rates have distinct predictive power beyond fertility, wealth and latitude. The correlation among SRB, fertility, GDP and life expectancy suggests that as human populations become more wealthy, the life expectancy increases (\( r = 0.80, p < 0.001 \)), total fertility is reduced (\( r = -0.75, p < 0.001 \)) and more sons are produced (\( r = 0.52, p < 0.001 \) (table 1). Although the effect of GDP is not statistically significant when other factors are present, it cannot be said that GDP is not involved. A nation with higher average GDP will also be able to afford better education and medical services, leading to reduced mortality and extended life expectancy, which may indirectly lead to increased son births, by enhancing the parental investment ability. These sources of endogeneity must be considered when interpreting present results. It should also be noted that, global variation in sex ratios is not solely related to life expectancy and mortality rate, rather, it is probably influenced by a variety of factors, including those mentioned here as well as factors that are yet unknown.

Life expectancy and mortality rates impose substantial influence on reproductive [57] and parental investment strategies in humans [58]. Unfortunately, demographic data do not allow us to distinguish sex-specific embryonic mortality, parental hormonal alterations around conception or other proximate mechanisms that may underlie the relationship between mortality rates and sex ratios. However, in the absence of known physiological mechanism, increase in testosterone level that occurs under favorable environmental conditions [59,60], which is linked with more male

Figure 1. Association between (a) life expectancy at birth (b) healthy life expectancy (c) adult mortality rate (d) infant mortality rate (e) under 5 mortality rate and (f) maternal mortality ratio and sex ratio at birth, after the effects of other explanatory variables on birth sex ratio are removed (table 2).
doi:10.1371/journal.pone.0023792.g001
births [61], might be a probable basis. Alternatively, the relation may be completely non-adaptive and outcome of various reproductive constraints and differential embryonic deaths [62], that occur in unfavorable environments. Adaptive or otherwise, the human natal sex ratio differences across the world may be influenced by existing environmental conditions and perceived future survival, as shown by the above results.

Supporting Information

Table S1 Descriptive statistics for countries included in this study.

Table S2 Multiple regression analysis predicting sex ratio at birth by life expectancy at birth (1), healthy life expectancy (2), adult mortality rate (3), infant mortality rate (4), under 5 mortality rate (5) and maternal mortality ratio (6), after controlling for fertility, wealth and latitude (n = 167). Except (3), all are ridge regression models at λ = 0.1, see methods for details. This analysis includes statistical outliers that were excluded from earlier regression models (Table 2).

References

1. Trivers RL, Willard DE (1973) Natural selection of parental ability to vary the sex ratio of offspring. Science 179: 90–92.
2. Rosenfeld CS, Blakely EW, Roberts RM (2004) Maternal diet and other factors affecting offspring sex ratio: a review. Biol Reprod 71: 1063–1070.
3. Pike TW, Petrie M (2003) Potential mechanisms of avian sex manipulation. Biol Rev Camb Philos Soc 78: 533–574.
4. Cameron EZ (2004) Facultative adjustment of mammalian sex ratios in support of the Trivers-Willard hypothesis: evidence for a mechanism. Proc Biol Sci 271: 1723–1728.
5. Gibson MA, Mace R (2003) Strong mothers bear more sons in rural Ethiopia. Proc Natl Acad Sci 270 Suppl 1: S108–109.
6. Mathews F, Johnson PJ, Neil A (2008) You are what your mother eats: evidence for maternal preconception diet influencing foetal sex in humans. Proc Biol Sci 275: 1661–1663.
7. Cagnacci A, Renzi A, Arangino S, Alessandrini C, Volpe A (2004) Influences of maternal weight on the secondary sex ratio of human offspring. Hum Reprod 19: 442–444.
8. Cagnacci A, Renzi A, Arangino S, Alessandrini C, Volpe A (2005) Interplay between maternal weight and seasons in determining the secondary sex ratio of human offspring. Fertil Steril 84: 246–248.
9. Pollet TV, Fawcett TW, Busank AP, Nettle D (2009) Sex-ratio biasing towards daughters among lower-ranking co-wives in rural Ethiopia. Biol Lett 5: 763–768.
10. Almond D, Edlund L (2007) Trivers-Willard at birth and one year: evidence from US natality data 1983–2001. Proc Biol Sci 274: 2491–2496.
11. Stein AD, Zybert PA, Lumey LH (2004) Acute undernutrition is not associated with excess of females at birth in humans: the Dutch hunger winter. Proc Biol Sci 271 Suppl 4: S138–141.
12. Stein AD, Barnett PG, Sellen DW (2004) Maternal undernutrition and the sex ratio at birth in Ethiopia: evidence from a national sample. Proc Biol Sci 271 Suppl 3: S37–39.
13. Heckerth T, Xing ZY (2006) Abnormal sex ratios in human populations: causes and consequences. Proc Natl Acad Sci U S A 103: 13271–13275.
14. Pararazini F, La Vecchia C, Levi F, Franceschi S (1998) Trends in male-female ratio among newborn infants in 29 countries from five continents. Hum Reprod 13: 1394–1396.
15. Fukuda M, Fukuda K, Shimizu T, Moller H (1998) Decline in sex ratio at birth after Kobe earthquake. Hum Reprod 13: 2321–2322.
16. Catalano RA (2003) Sex ratios in the two Germanies: a test of the economic stress hypothesis. Hum Reprod 18: 1972–1975.
17. Kernek A (2006) Secondary sex ratio variation during stressful times: the impact of the French revolutionary wars on a German parish (1787–1802). Am J Hum Biol 18: 806–821.
18. Graffelman J, Hoekstra RF (2000) A statistical analysis of the effect of warfare on the human secondary sex ratio. Hum Biol 72: 433–445.
19. Zorn B, Saurer V, Stastny D, Vrdoljak V (2002) Decline in sex ratio at birth after 10-day war in Slovenia: brief communication. Hum Reprod 17: 3173–3177.
20. Kaare C, Ansari-Lari M (2004) Sex ratio of birth during wartime and psychological tensions. Hum Reprod 19: 465.
21. Mathews TJ, Hamilton BE (2005) Trend analysis of the sex ratio at birth in the United States. Natl Vital Stat Rep 53: 1–17.
22. James WH (1971) Coital rate, sex ratio, and parental age. Lancet 1: 1294.
23. Nicolich MJ, Huebner WN, Schatten AR (2000) Influence of parental and biological factors on the male birth fraction in the United States: an analysis of birth certificate data from 1964 through 1988. Fertil Steril 73: 487–492.
24. Jacobsen R, Moller H, Engholm G (1999) Fertility rates in Denmark in relation to the years of preceding children in the family. Hum Reprod 14: 1127–1130.
25. Miller JL, England L, Grannerus S (2004) Cigarette smoking and the male-female sex ratio. Fertil Steril 79: 1243–1245.
26. James WH (2006) The sex ratios of offspring of diabetic parents. Diabet Med 23: 1043–1044.
27. James WH (2007) The sex ratio of offspring of patients with systemic lupus erythematosus. Lupus 16: 65–66.
28. James WH (2005) Offspring sex ratios of people exposed to electromagnetic fields. J Epidemiol Community Health 59: 810; author reply 810–811.
29. Vartianiemi T, Kartoavaara I, Tuonisto J (1999) Environmental chemicals and changes in sex ratio: analysis over 250 years in Finland. Environ Health Perspect 107: 813–815.
30. James WH (1971) Coital rate, sex ratio, and season of birth. Lancet 2: 159.
31. James WH (1986) Hormonal control of sex ratio. J Theor Biol 118: 427–441.
32. James WH (1997) Sex ratio, coital rate, hormones and time of fertilization within the cycle. Ann Hum Biol 24: 403–409.
33. James WH (2010) The categories of evidence relating to the hypothesis that mammalian sex ratios at birth are causally related to the hormone concentrations of both parents around the time of conception. J Biosoc Sci 43: 167–184.
34. Boldt CE (2005) The epigenetic environment: secondary sex ratio depends on differential survival in embryogenesis. Hum Reprod 20: 583–587.
35. Cagnacci A, Renzi A, Arangino S, Alessandrini C, Volpe A (2003) The male disadvantage and the seasonal rhythm of sex ratio at the time of conception. Hum Reprod 18: 885–887.
36. Cronk J (2007) Boy or girl? gender preferences from a Darwinian point of view. Reproductive bioscience online 15: 23–32.
37. Stein AD, Zybert PA, Lumey LH (2004) Acute undernutrition is not associated with excess of females at birth in humans: the Dutch Hunger Winter. Proceedings of the Royal Society of London Series B: Biological Sciences 271: S138–S141.
38. Pollet T, Nettle D (2010) No evidence for the generalized Trivers-Willard hypothesis from British and rural Guatemalan data. Journal of Evolutionary Psychology 8: 57–74.
39. Almond D, Edlund L (2007) Trivers-Willard at birth and one year: evidence from US natality data 1983–2001. Proceedings of Biological sciences/The Royal Society 274: 2491–2496.
40. Croquer E, Baali A, Hihi MK, Villena M, Vargas E (2006) Preference for sons or daughters among lower-ranking co-wives in Rwanda. Biol Lett 5: 765–768.
41. Braza F (2004) Human Prenatal Investment Affected by Maternal Age and Season of Fertilization. J Evolut Biol 18: 65–66.
42. Zorn B, Xing ZY (2006) Abnormal sex ratios in human populations: causes and consequences. Proc Natl Acad Sci U S A 103: 13271–13275.
43. Pararazini F, La Vecchia C, Levi F, Franceschi S (1998) Trends in male-female ratio among newborn infants in 29 countries from five continents. Hum Reprod 13: 1394–1396.
44. Ross CE, Miroslav K (2002) Family relationships, social support and subjective life expectancy. J Health Soc Behav 43: 315–334.
45. Godoy R, Reyes-Garcia V, McDarr T, Tanner S, Leonard W, et al. (2006) Why do mothers favor girls and fathers, boys? Human Nature 17: 169–189.
46. Ross CE, Miroslav K (2002) Family relationships, social support and subjective life expectancy. J Health Soc Behav 43: 489–499.
47. Guralnik JM, Land KC, Blazer D, Fillenbaum GG, Branch LG (1993) Health Status and Active Life Expectancy among Older Blacks and Whites. New England Journal of Medicine 329: 329–336.
48. Crimmins E, Hayward M, Saito Y (1994) Changing mortality and morbidity rates and the health status and life expectancy of the older population. Demography 31: 159–173.
47. Robine JM, Ritchie K (1991) Healthy life expectancy: evaluation of global indicator of change in population health. British Medical Journal 302: 457–460.
48. Murray CJL, Lopez AD (1997) Regional patterns of disability-free life expectancy and disability-adjusted life expectancy: Global Burden of Disease Study. The Lancet 349: 1347–1352.
49. Siegel M, Bradley EH, Kaal SV (2003) Self-rated Life Expectancy as a Predictor of Mortality: Evidence from the HRS and AHEAD Surveys. Gerontology 49: 265–271.
50. Hurd MD, McGarry K (2002) The Predictive Validity of Subjective Probabilities of Survival. The Economic Journal 112: 966–985.
51. Johns SE (2004) Subjective life expectancy predicts offspring sex in a contemporary British population. Proc Biol Sci 271 Suppl 6: S474–476.
52. Barber N (2004) Sex ratio at birth, polygyny, and fertility: a cross-national study. Soc Biol 51: 71–77.
53. Cameron EZ, Dalerum F (2009) A Trivers-Willard effect in contemporary humans: male-biased sex ratios among billionaires. PLoS One 4: e1195.
54. Navara KJ (2009) Humans at tropical latitudes produce more females. Biol Lett 5: 524–527.
55. Fox J (1991) Regression diagnostics. Newbury Park Calif.: Sage Publications.
56. Price B (1977) Ridge regression: Application to nonexperimental data. Psychological Bulletin 84: 759–766.
57. Hill EM, Jenkins J, Farmer L (2003) Family unpredictability, future discounting, and risk taking. Journal of Socio-Economics 32: 1381–1396.
58. Coall DA, Chisholm JS (2010) Reproductive development and parental investment during pregnancy: Moderating influence of mother’s early environment. American Journal of Human Biology 22: 143–153.
59. Halford C, Ekelius L, Anderzen I, Arnetz B, Svardsudd K (2010) Self-rated health, life-style, and psychoendocrine measures of stress in healthy adult women. Upsala Journal of Medical Sciences 115: 266–274.
60. Gray PB, Kruger A, Huisman HW, Wising MP, Vorster HH (2006) Predictors of South African male testosterone levels: the THUSA study. American Journal of Human Biology 18: 125–132.
61. James WH (1986) Hormonal control of sex ratio. Journal of Theoretical Biology 118: 427–441.
62. Tamimi RM, Lagiou P, Mucci LA, Hsieh C-C, Adami H-O, et al. (2003) Average energy intake among pregnant women carrying a boy compared with a girl. BMJ 326: 1245–1246.
63. Central Intelligence Agency (2010) World factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/index.html. Accessed on 20 June 2011.
64. World Health Organization 2010 Statistical Information System (WHOSIS),. Retrieved from http://who.int/whosis/en/. Accessed on 20 June 2011.
65. World Bank 2010 The world at a glance: key development indicators from the world bank. Retrieved from http://data.worldbank.org/indicator. Accessed on 20 June 2011.