Subjective life expectancy predicts offspring sex in a contemporary British population

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There is evidence that women who are in poor physical condition or who reside in deprived environments are more likely to give birth to daughters than to sons. Under deprived environmental conditions, or when in poor physical health, it has been hypothesized that parents should take into account the available resources and manipulate the sex of any children born. Using subjective life expectancy (SLE) as a measure of how an individual views their future health and environment, I demonstrate that there is an association between the sex of the first child and SLE in a sample of mothers from a contemporary British population (Gloucestershire, UK). SLE was a significant predictor of offspring sex: women who believed that they had longer to live were more likely to have had a male birth than women who thought they would die earlier. Detection of such a bias among the children of British mothers may provide evidence that the sex ratio under relatively affluent Western conditions can still be influenced by adverse environmental or poor maternal condition.

Keywords: sex ratios; Trivers–Willard; subjective life expectancy; reproductive strategy

1. INTRODUCTION

For humans, the Trivers–Willard hypothesis (Trivers & Willard 1973) suggests that if mothers are in good condition or have access to resources, they should invest more in sons from conception onward, as it is hypothesized that the reproductive success of sons is more variable than that of daughters (Trivers & Willard 1973), and that the physiological cost to the mother who bears a son is greater (Eogan *et al.* 2003; Tamimi *et al.* 2003). Growing and raising a successful son should lead to a high reproductive reward, but is a high-cost, high-risk reproductive option. Only those mothers who can afford to invest in their sons from conception onwards, increasing the probability that they will become desirable mates and survive to an age when they can reproduce, will be successful at passing on their genes via their sons. Mothers who are best able to bias their sex ratio pre-natally and their post-birth investment and resource allocation (for example, duration of breast feeding) in favour of sons when in good condition(s), and towards daughters when in poor

condition(s), will go on to have more descendants (Trivers & Willard 1973; Keller *et al.* 2001).

Evidence supporting a sex-ratio bias in humans has been found in a variety of human populations, although only a few studies have found evidence supporting the Trivers–Willard hypothesis in contemporary Western populations (Gaulin & Robbins 1991; Koziel & Ulijaszek 2001; for lack of support see Keller *et al.* 2001). Definitions of good or bad condition used when exploring sex-ratio bias have not just referred to actual physical condition of the parents (usually the mother) before and during pregnancy, but to the available resource base, parental social status and education level, general environmental adversity, and how many resources can be invested in offspring post-natally (Mackey 1993; Chacon-Puignau & Jaffe 1996; Koziel & Ulijaszek 2001). Women in good physical condition or living in high-quality, high-resource environments have been shown to have a sex ratio biased towards boys, whereas under conditions of environmental adversity or poor condition they have a sex ratio biased towards girls. Results have been found in populations from Venezuela (Chacon-Puignau & Jaffe 1996), Poland (Koziel & Ulijaszek 2001), Hungary (Bereczkei & Dunbar 1997) the United States (Mealey & Mackey 1990; Gaulin & Robbins 1991) and in a pastoralist community from Ethiopia, where it has been proposed that there is an association between the sex of the most recent child and maternal nutritional stress (Gibson & Mace 2003).

Environmental conditions and physical health appear to be reflected in subjective life expectancy (SLE), that is how much time an individual thinks they have left to live, with those living under conditions of economic hardship or with a physical impairment expecting to die sooner (Mirowsky & Ross 2000; Ross & Mirowsky 2002; Wardle & Steptoe 2003). SLE also appears to accurately predict actual age of death (Hurd & McGarry 1997). It is thus perhaps, the most psychologically salient variable that can be related to environmental stability and future outlook. For example, if an individual is in poor health, or has peers, parents or grandparents who are either sickly, dying or dead, they will discount the future and assume that they will die earlier (Hamermesh & Hamermesh 1983; Hurd & McGarry 1997; Mirowsky & Ross 2000). When all signs indicate that the future will be short, the optimal reproductive strategy should be to invest in offspring who will have the best chance under uncertain conditions of surviving to an age where they can reproduce. SLE should therefore affect reproductive strategies, including biasing sex of offspring. If the Trivers–Willard hypothesis holds, women with reduced SLE should bias towards daughters, whereas those with increased SLE should bias towards sons. Here, I demonstrate that such an association exists, in women from a modern Western population, between their SLE and the sex of their first-born child, with women who believe that they have longer to live being significantly more likely to have given birth to a son.

2. MATERIAL AND METHODS

Data were collected by self-completion postal questionnaire under a retrospective case–control study design in the county of Gloucestershire, southwest England. Within Gloucestershire, every woman who had given birth for the first time within the previous 4 years, while a teenager (12–19 years), was contacted by post in May 2001, as were a randomly selected equal number of women who had given birth to their first child between the ages of 20 and 27 years. These women were asked to complete a detailed questionnaire, and out of

Figure 1. Odds of having a son at first birth by SLE in years ($n = 667$). SLE is calculated by subtracting the age of the mother when she participated in the study from her imagined longevity. Odds are calculated by the following: $\log \text{ odds} = (\text{logit coefficient } (\beta) \times \text{SLE})$, $\text{odds} = \exp^{(\log \text{ odds})}$.

1759 questionnaires posted, 45% were received from eligible respondents. Ethical clearance for this project was obtained from the Gloucestershire Local Research Ethics Committee in March 2001 and all responses were held in the strictest confidence (Johns 2003). Data were analysed using SPSS, v. 11. Each woman was asked, among other questions relating to their pregnancy and current life circumstances, for their age when they gave birth, number of previous pregnancies not resulting in live birth, the sex of their first child, and the age at which they thought they would die. SLE was determined from the question 'if you had to take a guess about how old you will be when you die, what would you say?' with respondents asked to give the age in years. The woman's age when completing the questionnaire was subtracted from this imagined longevity to give the number of years that a respondent believed she had left to live (Mirowsky & Ross 2000).

3. RESULTS

Figure 1 shows the relationship between SLE and the odds of having a son. The average time a woman believed that she had left to live (SLE) was 53.16 years (s.d. = 11.60, range 2.25–105.7 years). A logistic regression analysis indicated that SLE was a significant predictor of the sex of the mother's first child ($n = 609$, $\chi^2 = 4.051$, d.f. = 1, $p < 0.05$), with mothers who believed that they had a longer time to live having increased odds of bearing a son ($\beta = 0.01$, odds ratio (OR) = 1.01, 95% confidence interval (CI) 1.00–1.03, $p < 0.05$). A second, multivariate, logistic regression model indicated that this remained the case when the number of previous pregnancies (not resulting in live birth) and the age of the mother when her baby was born were taken into account ($n = 609$, $\chi^2 = 7.860$, d.f. = 1, $p < 0.05$). For every extra year that a woman thought she was going to live, the odds that her first birth resulted in a boy increased by 1.01 ($\beta = 0.01$, OR = 1.01, 95% CI 1.00–1.03, $p = 0.02$). Overall, fewer males were first-born children of the 609 women used in analysis. There were 317 daughters and 292 sons, a sex ratio of 0.92 (cf. 1.05 for the UK as a whole for the same period: Office for National Statistics (ONS) 2004). Sex ratio in the sample appeared to be more male biased with increasing SLE (figure 2). Most women (73%) were primipara when they completed the questionnaire. The average time that had elapsed since the

Figure 2. Sex ratio by SLE. Sex ratios were calculated for each quartile of the SLE distribution.

respondents had given birth was 2.4 years. All mothers in the sample were below the average age at first birth for the UK (27.1 years in 2000 (ONS 2004)), but these results, even if less applicable to older mothers, should still reflect behavioural adaptations as increasing age at first birth appears to be a relatively recent trend in the British population (ONS 2004).

4. DISCUSSION

It has been proposed that a crucial factor influencing parental investment in offspring may be the local adult mortality rate (Chisholm 1993). The results presented here demonstrate that women who believe that they have a shorter time to live, perhaps as a result of their previous life-experiences and expectations about the future, will be less likely to give birth to 'expensive' sons and may therefore be attempting to maintain lineage survival under conditions that could truncate lifespan and reduce reproductive fitness.

A woman's SLE may be the observable product of an evolved, sub-conscious psychological mechanism that integrates environmental and physical conditions of the mother to determine her mortality risk, and so produce appropriate biases in both behavioural and physiological responses. Such a mechanism would help individuals to make decisions about the relative value of the future while taking account of present and past situations, and so influence their reproductive strategies (Hill *et al.* 1997; Chisholm 1999). Social environment and perceived physical condition have been found to influence testosterone levels (e.g. Huisman *et al.* 2002; Halford *et al.* 2003), and research suggests that higher testosterone levels can bias towards male births (Grant 1998). Thus a causal pathway may exist between environment, psychology, hormone response and offspring sex (Grant 2003), although the precise physiological mechanism of pre-birth sex-ratio biasing in humans has yet to be determined. However, the results are also consistent with a non-adaptive interpretation, whereby a low SLE can be viewed as a proxy measure of a poor-quality environment. In such a setting maternal condition could be compromised, thus leading

to a female-biased sex ratio given that sons are physiologically more costly than daughters to carry to term (Tamimi *et al.* 2003).

The results also establish that the offspring sex can still be influenced by adverse environmental or poor maternal conditions under relatively affluent Western conditions. Therefore, the effects of population inequalities on life expectancy and future outlook may be causing marked sex-ratio adjustments by mothers who live in environments where, when compared with the circumstances of others in the same population, adequate resources are scarce.

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- Bereczkei, T. & Dunbar, R. I. M. 1997 Female-biased reproductive strategies in a Hungarian gypsy population. *Proc. R. Soc. Lond. B* **264**, 17–22. (DOI 10.1098/rspb.1997.0003.)
- Chacon-Puignau, G. C. & Jaffe, K. 1996 Sex ratio at birth deviations in modern Venezuela: the Trivers–Willard effect. *Soc. Biol.* **43**, 257–270.
- Chisholm, J. S. 1993 Death, hope and sex: life-history theory and the development of reproductive strategies. *Curr. Anthropol.* **34**, 1–24.
- Chisholm, J. S. 1999 *Death, hope and sex: steps to an evolutionary ecology of mind and morality*. Cambridge University Press.
- Eogan, M. A., Geary, M. P., O'Connell, M. P. & Keane, D. P. 2003 Effect of fetal sex on labour and delivery: retrospective review. *Br. Med. J.* **326**, 137.
- Gaulin, S. J. & Robbins, C. J. 1991 Trivers–Willard effect in contemporary North American society. *Am. J. Phys. Anthropol.* **85**, 61–69.
- Gibson, M. A. & Mace, R. 2003 Strong mothers bear more sons in rural Ethiopia. *Proc. R. Soc. Lond. B* **270**(Suppl. 1), S108–S109. (DOI 10.1098/rspb.2003.0022.)
- Grant, V. J. 1998 *Maternal personality and the sex ratio*. London: Routledge.
- Grant, V. J. 2003 The maternal dominance hypothesis: questioning Trivers and Willard. *Evol. Psychol.* **1**, 96–107.
- Halford, C., Anderzen, I. & Arnetz, B. 2003 Endocrine measures of stress and self-rated health: a longitudinal study. *J. Psychosom. Res.* **55**, 317–320.
- Hamermesh, D. S. & Hamermesh, F. W. 1983 Does perception of life expectancy reflect health knowledge? *Am. J. Public Hlth* **78**, 911–914.
- Hill, E. M., Ross, L. T. & Low, B. S. 1997 The role of future unpredictability in human risk taking. *Hum. Nature* **8**, 287–325.
- Huisman, H. W., Van Rooyen, J. M., Malan, N. T., Eloff, F. C., Malan, L., Laubscher, P. J. & Schutte, A. E. 2002 Prolactin, testosterone and cortisol as possible markers of changes in cardiovascular function associated with urbanization. *J. Hum. Hypertens.* **16**, 829–835.
- Hurd, M. D. & McGarry, K. 1997 The predictive validity of subjective probabilities of survival. Working paper no. 6193. Cambridge MA: National Bureau of Economic Research.
- Johns, S. E. 2003 Environmental risk and the evolutionary psychology of teenage motherhood. PhD thesis, University of Bristol, UK.
- Keller, M. C., Nesse, R. M. & Hofferth, S. 2001 The Trivers–Willard hypothesis of parental investment: no effect in the contemporary United States. *Evol. Hum. Behav.* **22**, 343–360.
- Koziel, S. & Ulijaszek, S. J. 2001 Waiting for Trivers–Willard: do the rich really favor sons? *Am. J. Phys. Anthropol.* **115**, 71–79.
- Mackey, W. C. 1993 Relationships between the human sex ratio and the woman's microenvironment: 4 tests. *Hum. Nature* **4**, 175–198.
- Mealey, L. & Mackey, W. 1990 Variation in offspring sex ratio in women of differing social status. *Ethol. Sociobiol.* **11**, 83–95.
- Mirowsky, J. & Ross, C. E. 2000 Socioeconomic status and subjective life expectancy. *Soc. Psychol. Q.* **63**, 133–151.
- Office for National Statistics 2004 See <http://www.statistics.gov.uk>. Accessed 16 March 2004.
- Ross, C. E. & Mirowsky, J. 2002 Family relationships, social support and subjective life expectancy. *J. Soc. Hlth Behav.* **43**, 469–489.
- Tamimi, R. M., Lagiou, P., Mucci, L. A., Hsieh, C., Adami, H. & Trichopoulos, D. 2003 Average energy intake among pregnant women carrying a boy compared with a girl. *Br. Med. J.* **326**, 1245–1246.
- Trivers, R. L. & Willard, D. E. 1973 Natural selection of parental ability to vary the sex ratio of offspring. *Science* **179**, 90–92.
- Wardle, J. & Steptoe, A. 2003 Socioeconomic differences in attitudes and beliefs about healthy lifestyles. *J. Epidemiol. Commun. Hlth* **57**, 440–443.