Evolution and Human Behavior 33 (2012) 665–671

Evolution and Human Behavior

Original Article

Testosterone levels correlate with the number of children in human males, but the direction of the relationship depends on paternal education

Grazyna Jasienska[a,*], Michal Jasienski[b], Peter T. Ellison[c]

[a]*Department of Epidemiology and Population Studies, Jagiellonian University, Medical College, Krakow, Poland*
[b]*Center for Innovatics, Nowy Sacz Business School-National-Louis University, Nowy Sacz, Poland*
[c]*Department of Human Evolutionary Biology, Harvard University, Cambridge, MA*

Initial receipt 20 February 2011; final revision received 1 May 2012

Abstract

Most research shows that fatherhood is related to reduced testosterone (T) levels, but relationships between the number of children and T levels are not addressed. In humans, paternal care usually involves obtaining adequate resources to support children, which may require engaging in male–male competition and maintaining high T levels. We hypothesize that T levels in fathers should increase with increasing family size. In 78 Polish men, aged 30 to 77 years, the number of children was significantly correlated with paternal T levels, but the direction of this relationship was dependent on the fathers' education. In agreement with our hypothesis, in men with below-college education, T levels increased with increasing number of children. In contrast, in men with college education, the number of children was negatively related to paternal T levels. Drop in T levels throughout the day tended to be less pronounced the more children fathers had, irrespective of their educational level. Our results suggest that a hypothesis of simple trade-offs between mating and parenting effort may be too simplistic to explain changes in testosterone response to parenting in human males. In order to understand functional response of changes in T levels, it is crucial to account for family size and socioeconomic factors. However, due to the cross-sectional study design, we cannot exclude the possibility that T levels influenced reproductive behavior (rather than vice versa) and thus the number of children produced by men.

Keywords: Age variation; BMI; Fatherhood; Paternal care

1. Introduction

Testosterone (T) levels in males show variation in relation to mating and parenting effort. In human males, both pair-bonded men and fathers often have lower T levels when compared with single men and nonfathers (Berg & Wynne-Edwards, 2001; Burnham et al., 2003; Fleming, Corter, Stallings, & Steiner, 2002; Gettler, McDade, Feranil, & Kuzawa, 2011; Gray, Kahlenberg, Barrett, Lipson, & Ellison, 2002). In North American men, the majority of studies have documented that pair-bonding is associated with lower T levels [for review, see Gray & Campbell (2009)], and some studies found lower T levels in fathers when compared with nonfathers (Berg & Wynne-Edwards, 2001; Fleming et al., 2002). Several studies conducted in populations outside of North America also suggested that men in relationships and fathers have lower T levels. For example, in urban Jamaica, fathers had lower T than single men (Gray, Parkin, & Samms-Vaughan, 2007), while in urban China, fathers had lower T than either married nonfathers or unmarried men (Gray, Yang, & Pope, 2006). In rural Senegal, men with a higher investment in parental care had lower T levels (Alvergne, Faurie, & Raymond, 2009), and in Tanzanian Hadza hunter–gatherers, fathers had about 50% lower T compared to single men (Muller, Marlowe, Bugumba, & Ellison, 2009). In the Philippines, men who became fathers experienced more significant decline in T levels, in follow-up study, than single nonfathers (Gettler et al., 2011). It should be noted, however, that in some other populations, no statistically significant differences in T levels were detected when comparing men with regard to marital status or fatherhood [for review, see Gray & Campbell (2009)].

* Corresponding author. Grzegorzecka 20, 31-531 Krakow, Poland. Tel.: +48 12 433 2820.
E-mail address: jasienska@post.harvard.edu (G. Jasienska).

1090-5138/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.evolhumbehav.2012.05.001

Reduction in T levels observed in pair-bonded males and in fathers was suggested to have an adaptive significance (Wynne-Edwards & Reburn, 2000). In many species, reduced T levels may be responsible for behavioral changes such as lower male–male competitiveness and mate seeking, and more intense paternal care. However, such simple trade-offs between mating versus parenting efforts are more likely to be adaptive in seasonally breeding species without prolonged parental care, as suggested by the challenge hypothesis which was originally proposed to explain testosterone–aggression association in monogamous birds (Archer, 2006; Wingfield, Hegner, Dufty, & Ball, 1990). Humans, in contrast to many species, often experience a steady increase in family size, and parents raise several dependent offspring for a prolonged period of time. Therefore, a more complex relationship between parenting and testosterone levels should be expected.

Previous studies investigating relationships between fatherhood and T levels compared fathers with nonfathers (Gray et al., 2007; Muller et al., 2009) or analyzed changes in T levels in men who became fathers (Berg & Wynne-Edwards, 2001; Gettler et al., 2011; Storey, Walsh, Quinton, & Wynne-Edwards, 2000). Our cross-sectional study explores the relationship between parenting and T by testing whether the number of children is related to the father's T levels.

In many human societies, fathers are more often responsible for obtaining resources required to support the family, rather than expected to provide direct childcare. Successful resource acquisition may be, in turn, facilitated by such behaviors as male–male competition and dominance-related behaviors, which are supported by higher T levels (Gray & Campbell, 2009). Therefore, we suggest that, with increasing family size, an increase in testosterone levels in human males should be expected.

Parental investment and parental care vary in relation to socioeconomic status (Lawson & Mace, 2009). In many populations, high level of education is a positive predictor of high socioeconomic status (Ewert, 2012). We used education level as a proxy of socioeconomic status and tested relationships between number of children and paternal T levels in men who differed in their education.

2. Material and methods

Subjects were recruited in Krakow, Poland, in 1997 by advertisements and were not paid for their participation. One hundred and two men between the ages 30 and 77 (mean 55.0, S.D. 13.5), who reported not taking hormonal-based medication, collected saliva samples in their homes for 2 days: two morning samples, preferably immediately after waking up, and two evening samples, preferably after 7 p.m., following published protocols (Ellison, Lipson, & Meredith, 1989). Men brought samples to the laboratory where they filled out a self-administered questionnaire and where their anthropometric measurements were taken. Body weight was measured to the nearest 0.5 kg; body height, waist and hip circumferences, and several skinfolds were measured to the nearest 1 mm.

Eighteen men reported having no children (nine of them had never been married). In our sample, fathers and nonfathers did not differ in mean morning ($F_{1,86}$=1.229, p=.271) or evening ($F_{1,86}$=1.257, p=.265) log T levels, while controlling for age and body mass index (BMI) in covariance analyses (ANCOVAs). However, T levels in men who are fathers have often been reported as significantly lower than levels in men who did not have any children (Gray & Campbell, 2009), and we decided to remove nonfathers from further analyses. Six out of the remaining 84 men were also excluded from the analyses because either they did not answer questions about their educational level or their saliva samples were lost during laboratory procedures. Twenty-one men who reported having college education (at least 16 years of schooling) and 57 men with elementary, vocational school, or high school education (no more than 13 years of schooling) were included in final analyses (see Table 1 for descriptive statistics of both groups). Saliva samples were analyzed by radioimmunoassay for T (Ellison et al., 1989).

Mean morning and mean evening T levels were calculated for each man, and the values were log transformed in order to improve their statistical properties. T levels in men show circadian variation, where T levels are highest in the morning and decline during the day (Cooke, McIntosh, & McIntosh, 1993; Diver, Imtiaz, Ahmad, Vora, & Fraser,

Table 1
Descriptive characteristics of groups of fathers that differ in the level of education

	Fathers with below-college education Mean (S.D.), n=57	Fathers with college education Mean (S.D.), n=21
Age (years, p=.023)	57.6 (12.59)	49.9 (14.49)
Number of children (p=.05)	2.4 (1.06)	1.9 (0.65)
Age at first fatherhood (years, p=.006)	26.8 (3.83)	29.6 (3.39)
Body weight (kg, p=.997)	76.4 (12.86)	76.4 (10.90)
Body height (cm, p=.222)	170.4 (7.59)	172.7 (6.14)
BMI (kg/m^2, p=.399)	26.3 (3.67)	25.5 (3.84)
Morning testosterone levels (pmol/L)	224.2 (153.98)	317.2 (194.89)
Evening testosterone levels (pmol/L)	142.7 (97.13)	184.69 (105.18)
Morning/evening T ratio	2.07 (1.691)	1.81 (0.836)

The p values denote the significance of difference tested in univariate analyses of variance.

2003). T drop was calculated as mean log morning T minus mean log evening T. We tested the effects of age, BMI, and the number of children in groups of fathers who differed in the level of education on morning and evening T levels and on the magnitude of the T drop. Statistical analyses (multiple regression and analyses of covariance) were performed with the use of StatView, SuperANOVA, and JMP packages for the Macintosh.

3. Results

Preliminary analyses show that morning log T levels declined with increasing age (R^2=0.17, $F_{1,76}$=5.534, p=.0001) and with increasing BMI (R^2=0.16, $F_{1,75}$=4.763, p=.0004; Fig. 1). Evening T levels declined with increasing BMI (R^2=0.07, $F_{1,75}$=2.860, p=.023), but did not decline significantly with age (R^2=0.04, $F_{1,76}$=1.843, p=.07). The statistical significance of these results did not change in multiple regression analyses (when both age and BMI were included in a single model in order to remove their confounding effects on the dependent variable). The number of children was positively related to their father's age (R^2=0.09, $F_{1,76}$=6.493, p=.009).

Because education may influence parental investment and parental care, for further analyses, men were divided into two groups according to their educational level (below-college education versus college or university education). We performed analyses of covariance, with morning and evening log T levels as the dependent variables, educational level as the categorical variable, and age, BMI, and number of children as covariates. Since the interactions terms of education with age and BMI were not significant (at p>.3 in the case of morning T and p>.2 for evening T), they were pooled with the residual variance, and the ANCOVA was repeated. The age and BMI terms as covariates adjusting the dependent variable had a significant role in the case of morning T (respectively, $F_{1,71}$=8.951, p=.004 and $F_{1,71}$=8.697, p=.004) and did not have a significant role in the case of evening T (respectively, $F_{1,71}$=1.783, p=.186 and $F_{1,71}$=3.847, p=.054).

The overall effect of the number of children on morning and evening testosterone levels was not significant (respectively, $F_{1,71}$=0.993, p=.322, and $F_{1,71}$=0.118, p=.733). This is not surprising, however, since the direction of the relationship between the number of children and father's testosterone levels depended on the level of education: it was positive in the below-college group and negative in the college group. This complex effect was expressed in the significant interaction term (education × number of children) in the case of both morning testosterone ($F_{1,71}$=8.662, p=.004) and evening testosterone ($F_{1,71}$=5.370, p=.023). When controlling for age and BMI, in men with below-college education, the number of children was positively related to T, both for morning (R^2=0.14, p=.005) and evening levels (R^2=0.19, p=.0008), while in men with college education, the number of children showed a significant negative relationship with morning T (R^2=0.23, p=.026,) and evening T (R^2=0. 21, p=.03). We report here results of simple correlation analyses that used residuals from multiple regression because this simplified presenting results graphically (Fig. 2).

In addition, we repeated analyses including men who were married, but did not have any children—it added four

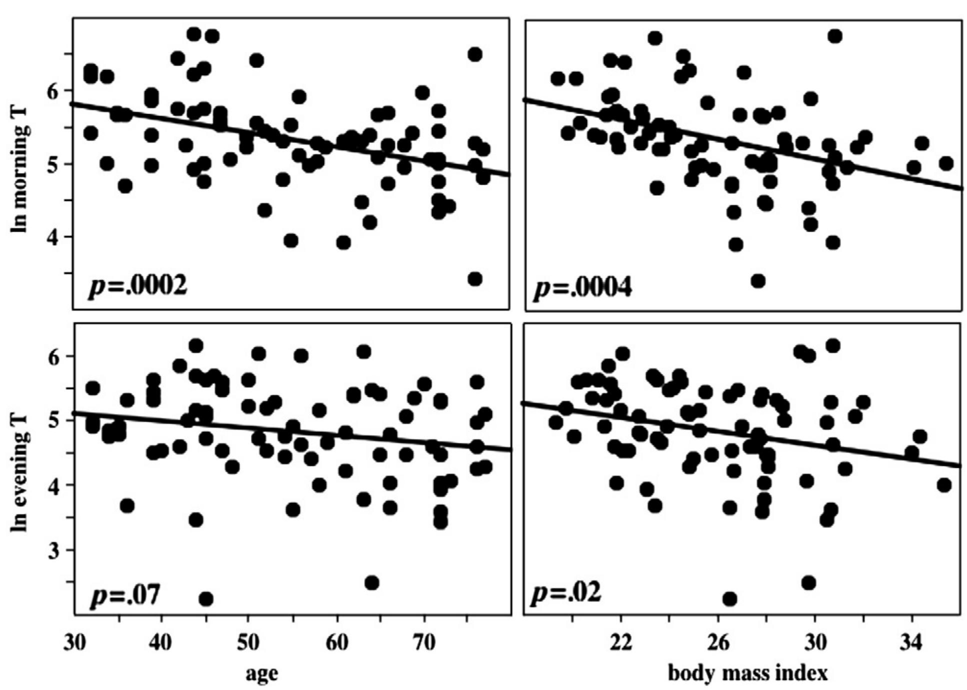

Fig. 1. Relationships between age (left panel) and BMI (right panel) and morning and evening T levels.

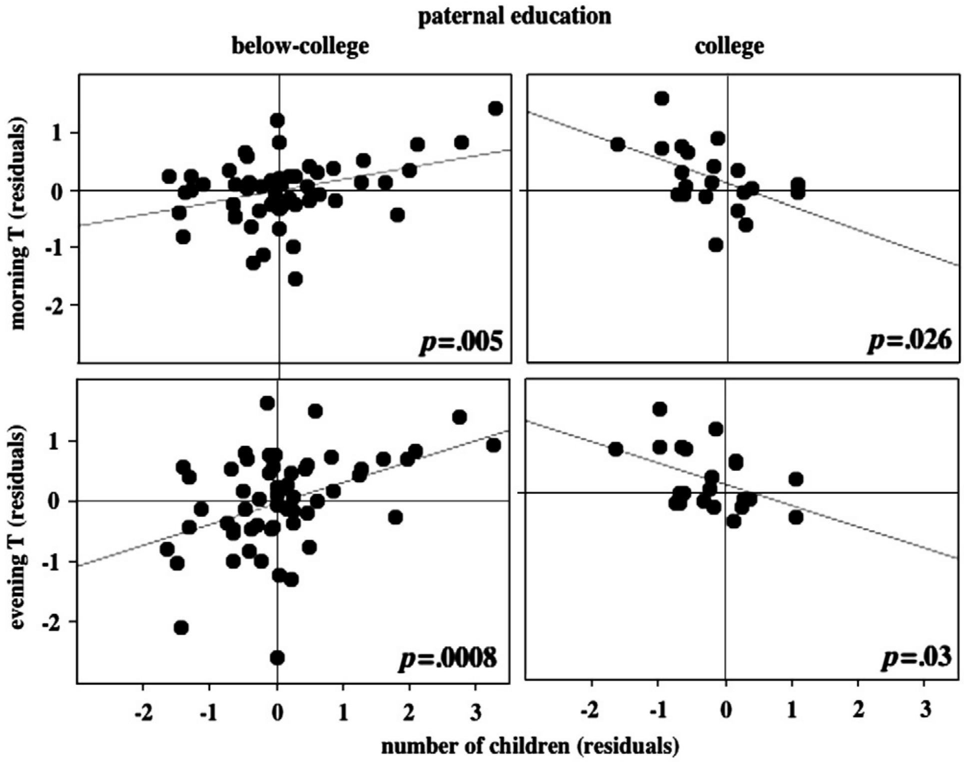

Fig. 2. Relationships between the number of children (expressed as residuals from a regression with age as independent variable), and morning and evening T levels (expressed as residuals obtained in a multiple regression analysis with age and BMI as independent variables) in groups of fathers who differed in their level of education.

individuals, but only to the below-college group. When the effects of age and BMI were accounted for, number of children had no significant effect in the case of mean morning (p=.188) and evening T (p=.903). Education × number of children interaction term was significant in the case of morning testosterone ($F_{1,75}$=6.777, p=.011) and marginally significant in the case of evening testosterone ($F_{1,75}$=3.772, p=.056). The direction of relationship between T levels and number of children therefore remained unchanged.

There was a significant negative association between number of children and the magnitude of the T drop ($F_{1,72}$=4.147, p=.045), but it did not depend on educational level (as shown by lack of interaction in ANCOVA between education and number of children; p=.987); more children meant smaller T drop during the day, independently of educational level, age, and BMI of the father.

4. Discussion

Our study shows that, in human males, the number of children significantly correlates with T levels; however, the direction of this relationship may depend on socioeconomic factors. In this Polish population, the father's level of education was an important factor to consider: in men with below-college education, T levels increased with increasing number of children, while in men with college education, the number of children was negatively related to T levels.

In species where offspring are raised to maturity in each reproductive season, lower T levels in males in response to pair-bonding and fatherhood are clearly adaptive, as they lead to such behavioral changes as less intense male–male competition and mate seeking, and more intense paternal care (Archer, 2006; Wingfield et al., 1990). In humans, however, who may have several immature offspring at any given time and in whom long-term paternal involvement is often essential for the child's well-being, each consecutive child requires additional resources.

Studies in many populations show that T levels in males may be reduced when the man is in a relationship and becoming a father (Alvergne et al., 2009; Berg & Wynne-Edwards, 2001; Burnham et al., 2003; Fleming et al., 2002; Gettler et al., 2011; Gray et al., 2002), but to our knowledge, previous studies did not address the issues of changes in T levels in relation to the size of the man's family. We hypothesized that T levels should increase with the birth of consecutive children, as the challenge of obtaining more resources increases. Obtaining additional resources may require engaging in male–male competition and may be more successful in socially dominant males. Social dominance, in turn, is linked to higher T levels (Gray & Campbell, 2009).

A positive relationship between the number of children and T levels observed in fathers with below-college education provides support for our hypothesis. A similar relationship was currently observed in Great Britain, where among men of low socioeconomic status, those with more children had higher levels of T (Magid, 2011). In our Polish study, in addition, in fathers, the number of children was negatively correlated with the magnitude of the drop in T levels that usually occurs during the day (Cooke et al., 1993; Diver et al., 2003). In other words, fathers with more children had less pronounced drop in T levels, i.e., were able to maintain higher T levels throughout the day, and this effect was independent of their educational attainment.

These results suggest that the relationship between family size and T levels can be mediated by social and psychological factors. It is likely that the observed relationship between T and number of children may result from differences in actual and perceived costs and benefits of having children. Men with a lower level of education often perceive children as economic assets (Emerson & Souza, 2007), and in addition, the actual costs of raising children are lower for them than for men with higher levels of education (Nettle, 2008; Yamauchi, 2010). For the latter, the costs of raising children include higher time involvement (Kaplan & Lancaster, 1998) and the often substantial financial costs of providing for their children's extracurricular activities and costs of college education. Lawson and Mace (2009) show that parents with middle and high socioeconomic status face stronger trade-offs between number of children and parental care than parents with lower socioeconomic status. They also documented that well-educated and relatively wealthy mothers attribute greater economic costs to having a higher number of children (Lawson & Mace, 2010).

It should be noted that our study was conducted in 1997, several years after the political and economic transition in Poland. During that period, the economic situation had already improved for many men with vocational education due to fast increasing employment opportunities for this group. In contrast, many college-educated men, especially those who, as in our study, had low-income positions at state universities, offices, and schools, experienced the burden of increases in costs of life. It is likely, therefore, that the costs and benefits of having children differed in men depending on their socioeconomic status. Results described by this study are context-dependent, and they should not be interpreted as a suggestion that paternal education should in a similar way interfere in the relationship between the number of children and paternal T levels in all human populations. For example, in British men of high socioeconomic status, family size or age of children does not predict paternal T levels (Magid, 2011).

This study had a cross-sectional design, and fathers did not necessarily still have direct contact with all of their children because some of the children were already adults. However, parenting is a factor that may have a long-term impact on many aspects of behavior, physiology, and health. In women, due to high energetic and physiological costs of reproduction, high parity is related to increased risk of several diseases (Hinkula, Kauppila, Nayha, & Pukkala, 2006; Skilton, Serusclat, Begg, Moulin, & Bonnet, 2009) and even to a reduced longevity (Jasienska, 2009; Jasienska, Nenko, & Jasienski, 2006; Le Bourg, 2007; Jasienska, 2013). In men, fathers differ from nonfathers in their social connections, family relationships, and work behavior (Eggebeen & Knoester, 2001), and the number of children is related to health risk factors, for example, smoking cessation (Jarvis, 1996) and subsequent risk of obesity (Bakhshi et al., 2008; Weng, Bastian, Taylor, Moser, & Ostbye, 2004). In Polish rural populations, the number of daughters was positively related to the longevity of their fathers (Jasienska et al., 2006). It is, therefore, likely that having children may influence paternal health and physiology, including T levels, not only through direct physical contact with children but also during years when such contacts are no longer frequent.

In a cross-sectional study like ours, the direction of a causal link between two variables cannot, in principle, be determined with certainty, which leaves room for alternative hypotheses. An alternative and opposite explanation of our results would be that T levels influence man's reproductive behavior and its outcomes, including number of children. Levels of T may be important for male–male competition and mate choice (Gray & Campbell, 2009), and in the Philippines, men with higher T were more likely to become fathers than men with lower T levels (Gettler et al., 2011). It is likely that, among men with lower educational status, those with high T have children earlier, whereas among well-educated men, those with high T have children later (Ruth Mace, personal communication). Postponing reproduction (and thus lowering their lifetime reproductive success) may be beneficial by allowing them to apply their testosterone-dependent behaviors to more effectively pursue their career-oriented goals.

It is important to emphasize that due to the cross-sectional design of the study, we are not able to distinguish between these alternative hypotheses: it is equally likely that children impact paternal T levels or, alternatively, that T levels influence reproductive behavior of men and thus are related to the number of children that they have.

T levels in men are important correlates of health and behavior. Levels of this hormone vary in relation to numerous factors. In many populations, T levels decline with age (Ellison et al., 2002; Feldman et al., 2002) [but see Bribiescas (2005)] and increasing body fat levels (Jensen et al., 2004; Tamimi et al., 2001), and we observed similar relationships in the studied population. Variation among populations in mean T levels that may be due to differences in nutritional status is well established (Bribiescas, 1995; Ellison et al., 2002). More recent research points to the importance of marriage and fatherhood as determinants of T levels. The results of our study suggest that not only fatherhood but also the number of children may be a significant predictor of T levels in men. Furthermore, we suggest that a hypothesis of a reduction in T levels in fathers, indicating simple trade-offs between mating and parenting effort, should not be directly translated from research on seasonally breeding species to human males, whose children are often dependent and require substantial resources for many years.

Acknowledgments

We are grateful to the Yale University Program in Reproductive Ecology (formerly Center for Human and Primate Reproductive Ecology, CHaPRE) for financial support; to Dr. Andrzej Rys, Dr. Zbigniew Król, Lucyna Plawecka, and Dr. Tomasz Owerkowicz for their help with organizing this study; and to Dr. Susan Lipson, Ira Lindsay, and Kiemanh Pham for their assistance with hormonal analyses.

References

Alvergne, A., Faurie, C., & Raymond, M. (2009). Variation in testosterone levels and male reproductive effort: insight from a polygynous human population. *Hormones and Behavior*, *56*, 491–497.

Archer, J. (2006). Testosterone and human aggression: an evaluation of the challenge hypothesis. *Neuroscience and Biobehavioral Reviews*, *30*, 319–345.

Bakhshi, E., Eshraghian, M. R., Mohammad, K., Foroushani, A. R., Zeraati, H., & Fotouhi, A., et al. (2008). The positive association between number of children and obesity in Iranian women and men: results from the National Health Survey. *BMC Public Health*, *8*, 213–218.

Berg, S. J., & Wynne-Edwards, K. E. (2001). Changes in testosterone, cortisol, and estradiol levels in men becoming fathers. *Mayo Clinic Proceedings*, *76*, 582–592.

Bribiescas, R. G. (1995). Testosterone levels among Ache hunter–gatherer men. A functional interpretation of population variation among adult males. *Human Nature*, *7*, 163–188.

Bribiescas, R. G. (2005). Age-related differences in serum gonadotropin (FSH and LH), salivary testosterone, and 17-beta estradiol levels among Ache Amerindian males of Paraguay. *American Journal of Physical Anthropology*, *127*, 114–121.

Burnham, T. C., Chapman, J. F., Gray, P. B., McIntyre, M. H., Lipson, S. F., & Ellison, P. T. (2003). Men in committed, romantic relationships have lower testosterone. *Hormones and Behavior*, *44*, 119–122.

Cooke, R. R., McIntosh, J. E. A., & McIntosh, R. P. (1993). Circadian variation in serum-free and non-SHBG-bound testosterone in normal men—measurements, and simulation using a mass-action model. *Clinical Endocrinology*, *39*, 163–171.

Diver, M. J., Imtiaz, K. E., Ahmad, A. M., Vora, J. P., & Fraser, W. D. (2003). Diurnal rhythms of serum total, free and bioavailable testosterone and of SHBG in middle-aged men compared with those in young men. *Clinical Endocrinology*, *58*, 710–717.

Eggebeen, D. J., & Knoester, C. (2001). Does fatherhood matter for men? *Journal of Marriage and the Family*, *63*, 381–393.

Ellison, P. T., Bribiescas, R. G., Bentley, G. R., Campbell, B. C., Lipson, S. F., & Panter-Brick, C., et al. (2002). Population variation in age-related decline in male salivary testosterone. *Human Reproduction*, *17*, 3251–3253.

Ellison, P. T., Lipson, S. F., & Meredith, M. D. (1989). Salivary testosterone levels in males from the Ituri Forest of Zaïre. *American Journal of Human Biology*, *1*, 21–24.

Emerson, P. M., & Souza, A. P. (2007). Child labor, school attendance, and intrahousehold gender bias in Brazil. *World Bank Economic Review*, *21*, 301–316.

Ewert, S. (2012). What it's worth: field training and economic status in 2009. *Current Population Reports US Census Bureau*, Available at: http://www.census.gov/prod/2012pubs/p70-129.pdf.

Feldman, H. A., Longcope, C., Derby, C. A., Johannes, C. B., Araujo, A. B., & Coviello, A. D., et al. (2002). Age trends in the level of serum testosterone and other hormones in middle-aged men: longitudinal results from the Massachusetts Male Aging Study. *The Journal of Clinical Endocrinology and Metabolism*, *87*, 589–598.

Fleming, A. S., Corter, C., Stallings, J., & Steiner, M. (2002). Testosterone and prolactin are associated with emotional responses to infant cries in new fathers. *Hormones and Behavior*, *42*, 399–413.

Gettler, L. T., McDade, T. W., Feranil, A. B., & Kuzawa, C. W. (2011). Longitudinal evidence that fatherhood decreases testosterone in human males. *Proceedings of the National Academy of Sciences of the United States of America*, *108*, 16194–16199.

Gray, P. B., & Campbell, B. C. (2009). Human males testosterone, pair-bonding, and fatherhood. In P. T. Ellison, & P. B. Gray (Eds.), *Endocrinology of social relationship* (pp. 270–293). Cambridge, MA: Harvard University Press.

Gray, P. B., Kahlenberg, S. M., Barrett, E. S., Lipson, S. F., & Ellison, P. T. (2002). Marriage and fatherhood are associated with lower testosterone in males. *Evolution and Human Behavior*, *23*, 193–201.

Gray, P. B., Parkin, J. C., & Samms-Vaughan, M. E. (2007). Hormonal correlates of human paternal interactions: a hospital-based investigation in urban Jamaica. *Hormones and Behavior*, *52*, 499–507.

Gray, P. B., Yang, C. F. J., & Pope, H. G. (2006). Fathers have lower salivary testosterone levels than unmarried men and married non-fathers in Beijing, China. [PhD dissertation]. *Proceedings of the Royal Society B-Biological Sciences*, *273*, 333–339.

Hinkula, M., Kauppila, A., Nayha, S., & Pukkala, E. (2006). Cause-specific mortality of grand multiparous women in Finland. *American Journal Of Epidemiology*, *163*, 367–373.

Jarvis, M. J. (1996). The association between having children family size and smoking cessation in adults. *Addiction*, *91*, 427–434.

Jasienska, G. (2009). Reproduction and lifespan: trade-offs, overall energy budgets, intergenerational costs, and costs neglected by research. *American Journal of Human Biology*, *21*, 524–532.

Jasienska, G. (2013). *The fragile wisdom. An evolutionary view on women's biology and health*. Cambridge, MA: Harvard University Press.

Jasienska, G., Nenko, I., & Jasienski, M. (2006). Daughters increase longevity of fathers, but daughters and sons equally reduce longevity of mothers. *American Journal of Human Biology*, *18*, 422–425.

Jensen, T. K., Andersson, A. M., Jorgensen, N., Andersen, A. G., Carlsen, E., & Petersen, J. H., et al. (2004). Body mass index in relation to semen quality and reproductive hormones among 1,558 Danish men. *Fertility and Sterility*, *82*, 863–870.

Kaplan, H., & Lancaster, J. (1998). Human parental investment and fertility: the life histories of men in Albuquerque. In A. Booth, & A. Crouter (Eds.), *Men in families. When do they get involved? What difference does it make?* (pp. 55–109). NJ Erlbaum: Mahwah.

Lawson, D. W., & Mace, R. (2009). Trade-offs in modern parenting: a longitudinal study of sibling competition for parental care. *Evolution and Human Behavior*, *30*, 170–183.

Lawson, D. W., & Mace, R. (2010). Optimizing modern family size. *Human Nature-an Interdisciplinary Biosocial Perspective*, *21*, 39–61.

Le Bourg, E. (2007). Does reproduction decrease longevity in human beings? *Ageing Research Reviews*, *6*, 141–149.

Magid, K. S. (2011). *Reproductive ecology and life history of human males: a migrant study of Bangladeshi men*. London: University College London.

Muller, M. N., Marlowe, F. W., Bugumba, R., & Ellison, P. T. (2009). Testosterone and paternal care in East African foragers and pastoralists. *Proceedings of the Royal Society B-Biological Sciences*, *276*, 347–354.

Nettle, D. (2008). Why do some dads get more involved than others? Evidence from a large British cohort. *Evolution and Human Behavior*, *29*, 416–423.

Skilton, M. R., Serusclat, A., Begg, L. M., Moulin, P., & Bonnet, F. (2009). Parity and carotid atherosclerosis in men and women: insights into the roles of childbearing and child-rearing. *Stroke*, *40*, 1152–1157.

Storey, A. E., Walsh, C. J., Quinton, R. L., & Wynne-Edwards, K. E. (2000). Hormonal correlates of paternal responsiveness in new and expectant fathers. *Evolution and Human Behavior*, *21*, 79–95.

Tamimi, R., Mucci, L. A., Spanos, E., Lagiou, A., Benetou, V., & Trichopoulos, D. (2001). Testosterone and oestradiol in relation to tobacco smoking, body mass index, energy consumption and nutrient intake among adult men. *European Journal of Cancer Prevention*, *10*, 275–280.

Weng, H. L. H., Bastian, L. A., Taylor, D. H., Moser, B. K., & Ostbye, T. (2004). Number of children associated with obesity in middle-aged women and men: results from the Health and Retirement Study. *Journal of Womens Health*, *13*, 85–91.

Wingfield, J. C., Hegner, R. E., Dufty, A. M., & Ball, G. F. (1990). The challenge hypothesis—theoretical implications for patterns of testosterone secretion, mating systems, and breeding strategies. *The American Naturalist*, *136*, 829–846.

Wynne-Edwards, K. E., & Reburn, C. J. (2000). Behavioral endocrinology of mammalian fatherhood. *Trends in Ecology & Evolution*, *15*, 464–468.

Yamauchi, C. (2010). Parental investment in children: differential pathways of parental education and mental health. *The Economic Record*, *86*, 210–226.