

Women's height, reproductive success and the evolution of sexual dimorphism in modern humans

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Recent studies have shown that, in contemporary populations, tall men have greater reproductive success than shorter men. This appears to be due to their greater ability to attract mates. To our knowledge, no comparable results have yet been reported for women. This study used data from Britain's National Child Development Study to examine the life histories of a nationally representative group of women. Height was weakly but significantly related to reproductive success. The relationship was U-shaped, with deficits at the extremes of height. This pattern was largely due to poor health among extremely tall and extremely short women. However, the maximum reproductive success was found below the mean height for women. Thus, selection appears to be sexually disruptive in this population, favouring tall men and short women. Over evolutionary time, such a situation tends to maintain sexual dimorphism. Men do not use stature as a positive mate-choice criterion as women do. It is argued that there is good evolutionary reason for this, because men are orientated towards cues of fertility, and female height, being positively related to age of sexual maturity, is not such a cue.

Keywords: height; sexual dimorphism; mate choice; human evolution

1. INTRODUCTION

Several recent studies have found that, for men, there is a positive relationship between male stature and reproductive success in contemporary populations (Pawlowski *et al.* 2000; Mueller & Mazur 2001; Nettle 2002*a*). In the first two of these studies, taller than average men were shown to have more children than matched men of average height. The third study showed that, for a cohort of British men not quite at the end of their reproductive careers, taller than average men had a higher lifetime number of cohabiting partners and decreased probabilities of childlessness or having no major relationship. There was a stabilizing effect on men of extreme height, who had increased health problems and depressed reproductive success.

These findings corroborate a long-established result from the attractiveness literature; taller men are found to be more attractive than those of average height (Gillis & Avis 1980; Feingold 1982; Shepperd & Strathman 1989; Jackson & Ervin 1992; Hensley 1994). This effect is a plausible explanation of the observed reproductive success differentials. Possible alternative hypotheses in terms of greater socioeconomic success of taller men, which has an indirect effect on their ability to attract partners, were tested in the data of Mueller & Mazur (2001) and Nettle (2002*a*), and not supported. The men with the highest reproductive success in Nettle's study were exactly the same height—6 foot (1.8 m), which was 2.2 inches (5.5 cm) taller than the cohort mean—as those rated the most attractive by women in the attractiveness study of Hensley (1994).

The relationship between stature and reproductive success among corresponding samples of women has not yet, to our knowledge, been reported. The general expectation is a U-shaped relationship (Vetta 1975), as there are known health problems at both extremes of the height dis-

tribution (Heliovaara *et al.* 1991; Peck 1992; Silventoinen *et al.* 1999; Hilavki-Clarke *et al.* 2001; Michaud *et al.* 2001). The crucial question, though, is where the maximum value of the U falls. For men, it is above the mean height. The attractiveness findings in this area predict that, for women, it will not be above the mean because height appears to have no attractiveness consequences for females as it does for males (Hensley 1994). The results have implications for our understanding of the selection pressures acting on human stature. If the optimal level of reproductive success for women is also above their mean height, then the entire population is under directional selection. If the female optimum is at or below their mean height, then the population is undergoing sexually disruptive selection, a process whose effect is to maintain or increase the level of sexual dimorphism.

In this paper, results are reported for the female half of the nationally representative social cohort for which male data were presented in Nettle (2002*a*). The objectives of the analysis are (i) to describe the relationship between stature and reproductive success for the women; (ii) to investigate whether such relationships are due to mate selection on the basis of stature *per se*, or some other factor such as health or socioeconomic status; and (iii) to look for evidence that selection on stature in this population is sexually disruptive. The implications of the results for the evolution of human sexual dimorphism in terms of size and mate preferences are then discussed.

2. METHODS

The data used are from Britain's National Child Development Study, which is an ongoing longitudinal investigation of social, economic and health outcomes for all of the children born in Great Britain in a single week in March 1958 (Butler & Bonham 1963; Fogelman 1983; Ferri 1993; Bynner *et al.* 2001). The variables derived for the present analysis are mostly but not all

the same as those described in detail for the men in the cohort in Nettle (2002a). The stature variable 'height' is the measured height of the individual, in metres, at the age of 23 years in 1971. This is a continuous variable, but some of its values are much more frequent than others, presumably due to the measurer taking the nearest scale point. It has been used here in a form that is standardized for sex ' z -height', with a mean of 0 and a standard deviation (s.d.) of 1. Thus, a woman with a z -height of 2 is two s.d. above the mean height for women; a man with a z -height of -0.5 is half of a s.d. below the mean height for men.

Socioeconomic status is provided by the traditional I–V class classification 'class'. Other work with this cohort has shown that this, though strictly speaking a set of categories, can be treated as a continuous scale of decreasing socioeconomic status (Nettle 2002b). It is a somewhat less accurate scale for women than men, because it is occupationally defined. Because women with small children often move out of or into the margins of the labour market, they can sometimes receive a low classification regardless of their true socioeconomic position. This problem does not invalidate the classification entirely, but it means that for women it is sometimes useful to use an ancillary measure, in this case father's social class 'fclass'. This is also an important variable in its own right, as it is robustly related to stature, presumably through childhood nutrition and conditions.

Some health information was also available. Cohort members were asked in the year 2000 if they suffered any kind of long-standing illness or disability that impaired their work. This is the basis of the 'illness' variable, which is dichotomous. Because U-shaped relationships are expected, the method used is quadratic regression using the model $Y = AX^2 + BX + C$. This procedure also detects linear relationships, by returning an equation with A close to zero.

3. RESULTS

The mean height for the women was 1.624 m, with a s.d. of 0.066 m. This is 15 cm less than their male peers. Previous analysis (Nettle 2002a) showed that, for the men, there was no significant relationship between total number of children and height. This may well have been due to the men not yet being at the end of their reproductive careers, because such relationships have been found elsewhere (Pawlowski *et al.* 2000; Mueller & Mazur 2001).

For the women, there is a significant but weak quadratic relationship between height and number of children ($r = 0.08$, d.f. = 3551, $p < 0.001$). This could be an artefact of socioeconomic position, because social class is linearly related to height (for women, $r = 0.11$, d.f. = 3962, $p < 0.001$), and social class and number of children are linearly related ($r = 0.19$, d.f. = 3987, $p < 0.001$). This is because it becomes increasingly difficult for women to maintain occupations in the higher categories when they have children (and particularly as the number of their children increases), so women with several children tend to be categorized in lower occupational classes. When this relationship is corrected for statistically (by taking the dependent variable as 'children' $- 0.263 \times$ 'class'), there is still a weak curvilinear relationship between height and number of children ($r = 0.05$, d.f. = 3551, $p < 0.005$). The relationship is shown in figure 1. It has the expected U-shape, with decrements at both extremes. Most importantly, though, the maximal number of children is

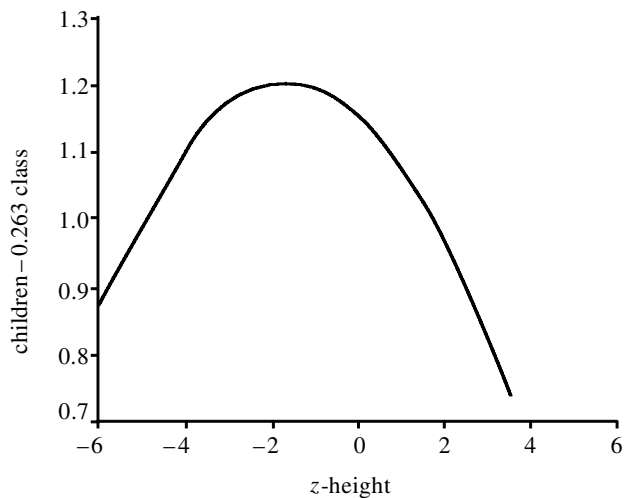


Figure 1. Plot of the regression relationship between standardized height and number of children, controlled for social class.

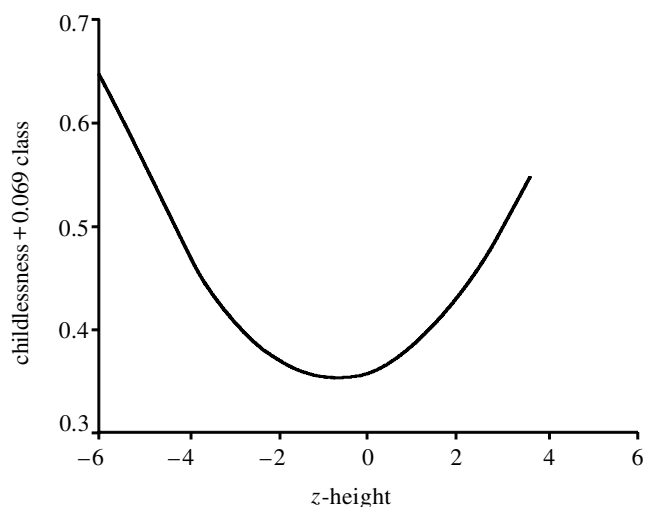


Figure 2. Regression of the probability of childlessness, controlled for social class, against standardized height.

well below the mean of height, at z -height = -1.7 . Thus the effect, though weak, indicates selection in the direction of shortness for women. The same conclusion is reached using father's social class rather than own social class as the control for socioeconomic status (data not shown).

This suggestion is backed up by an examination of the relationship of height to the probability of childlessness. There is a significant quadratic relationship ($r = 0.08$, d.f. = 4393, $p < 0.001$). Again, it does not appear to be an artefact of social class. There is a significant relationship between childlessness and class ($r = 0.16$, d.f. = 3987, $p < 0.001$), but when this is statistically controlled for, the quadratic relationship between height and childlessness remains with an only slightly diminished r -value ($r = 0.06$, d.f. = 3551, $p < 0.005$; figure 2). The stature with the minimum probability of childlessness is again below the mean (at z -height = -0.7).

The reason for the lowered reproductive success at the extremes appears to be that women are less likely to find

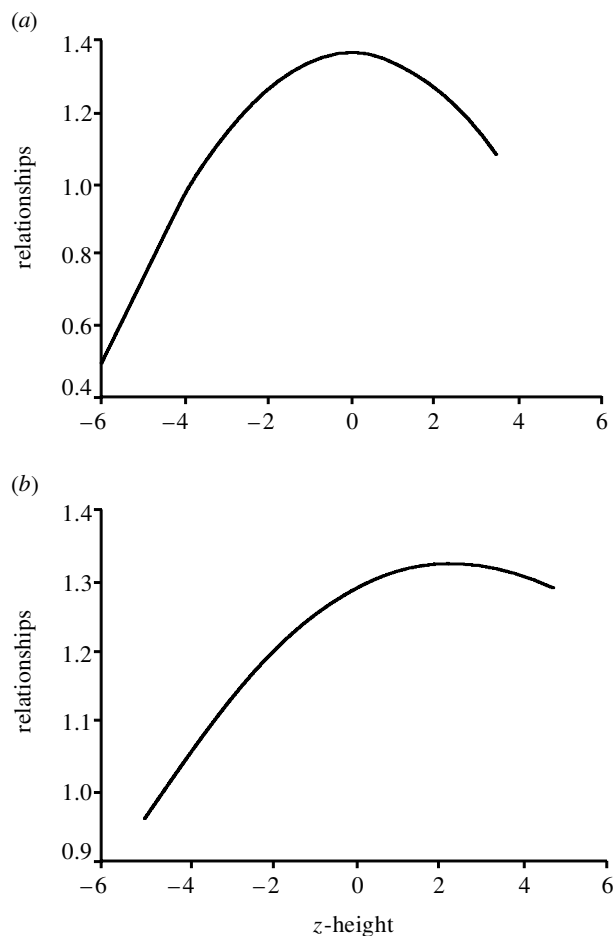


Figure 3. Regression of number of marriages or cohabiting relationships for (a) women and (b) men against standardized height.

a husband or long-term partner. Figure 3 shows the regression of number of marriages or long-term relationships against height ($r = 0.04$, d.f. = 4444, $p < 0.05$). This relationship does not need to be corrected for socioeconomic status because there is no relationship between a woman's number of partners and her own ($r = 0.01$, d.f. = 4031, n.s.) or her father's ($r = 0.01$, d.f. = 4585, n.s.) social class. For comparison, the same curve is shown for the men (figure 3b). The female curve (figure 3a) has its optimum almost exactly on zero, with a decline above this point, whereas for men, increasing height is associated almost monotonically with increasing numbers of relationships until the top tail of the distribution (the maximum is at 2.4 s.d. above a mean that is already much higher than the women's). For women, it might be argued that reproductive success is affected not so much by the total number of relationships as by the probability of having at least one. However, this probability shows exactly the same pattern as the total number of relationships ($r = 0.06$, d.f. = 4444, $p < 0.001$).

It is possible that the reproductive success patterns associated with height are partly due to a relationship between height and health; those at the extremes of height may suffer serious health problems and as a consequence be less likely to marry or have children. The probability of having a long-standing illness or disability is indeed related to height for the women ($r = 0.04$, d.f. = 4898, $p < 0.05$).

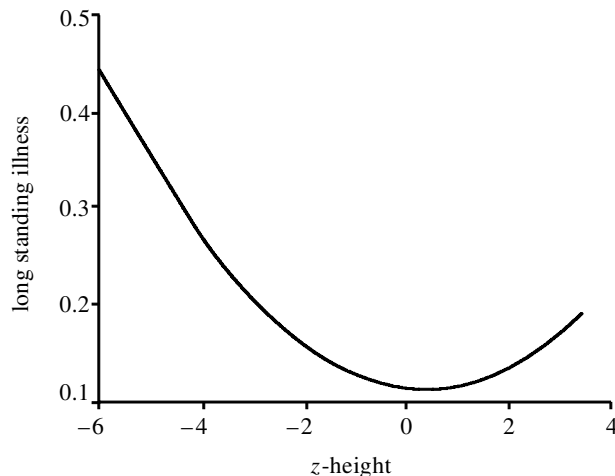


Figure 4. Regression relationship between standardized height and the probability of having a long-standing illness.

The relationship is U-shaped and centred just above the mean (figure 4). To test whether this relationship accounted for association between height and reproductive success, regressions were rerun excluding all individuals reporting a long-standing illness.

The regressions involving number of children remained significant ('z-height' and 'children' controlled for social class: $r = 0.05$, d.f. = 3271, $p < 0.05$; 'z-height' and 'childlessness' controlled for social class: $r = 0.06$, d.f. = 3845, $p < 0.001$). However, those involving number of relationships did not ('z-height' and 'relationships': $r = 0.03$, d.f. = 3889, n.s.; 'z-height' and 'no relationship': $r = 0.03$, d.f. = 3889, n.s.). Thus, part, though perhaps not all, of the effect of stature on reproductive behaviour in women is mediated through health status.

4. DISCUSSION

These data clearly show that there is no advantage at all to women in terms of reproductive success in being taller than average. On the basis of children born by maternal age 42, correcting for social class, the optimal height for a woman is 0.7 to 1.7 s.d. below the mean. This equates to 1.58 m or 1.51 m, whereas the mean in the population is 1.62 m. By contrast, the men's optimum, derived not in terms of number of children but probability of marriage, was 1.83 m compared with a population mean of 1.77 m (Nettle 2002a).

This association is weak, accounting for less than 1% of the variation in reproductive success. Nonetheless, it is highly significant, and when iterated over generations it could represent a significant evolutionary force. If the finding holds more widely than this particular cohort, then selection on stature is still going on, albeit weakly, in contemporary humans, and its form is sexually disruptive. The finding from the psychology of attractiveness (Hensley 1994) that height is used as a mate-selection characteristic by women but not men, is an effect with real-world consequences that are being played out in the British population.

The reduction in marriage and child-bearing among tall women is related to health, which is more likely to be impaired at the extremes of stature. However, a similar U-

shaped relationship between height and health holds for men, and this is clearly not enough to nullify the advantages that tall men have in attracting marriage partners. An additional factor for tall women could be the reduced availability of potential partners. There is a very widespread tendency for men to choose women shorter than themselves and/or women to choose men taller than themselves (Gillis & Avis 1980). Given the mean difference in male and female heights (15 cm) and the dispersal of the distributions, a women in the tallest quartile of height only has the choice of around three quarters of all men if the male-taller norm in mate selection is to be preserved. Women in the second quartile, by contrast, have essentially the full range of men to choose from.

Stature is particularly interesting within studies of human mate choice, because it is a reversal of the usual generalization that men pay more attention to physical characteristics, whilst women pay more attention to indications of status and resources (Buss 1989; Kenrick & Keefe 1992; Waynforth & Dunbar 1995). The usual pattern is thought to exist because men seek to maximize fertility in their partners (for which youth and physical appearance are cues), whilst women seek to maximize potential resource investment in offspring, at least in long-term matings. The current results suggest why sexual dimorphism in stature persists in the human population. Large male size presumably had a direct fitness advantage under ancestral conditions, perhaps in male–male competition, as is often argued for other mammalian species (Alexander *et al.* 1979). Such direct selection pressures may well be relaxed under more recent living conditions. However, the vestige of the tall-male advantage lives on in terms of a female mate-selection preference that appears to endure.

Why the same preference has not evolved among men is not obvious. It may well be the case that there was not, under ancestral conditions, any direct fitness advantage to a woman in being taller than average. However, taller women would have had taller sons. In this cohort, the correlation between mother and son height is 0.43 ($n = 4725$, $p < 0.001$). This correlation is an amalgam of the genetic and shared-environment components of stature, but there is general evidence that height is highly heritable and polygenic (Chatterjee *et al.* 1999). Thus, other things being equal, men choosing tall women would have increased fitness because they were thereby designing tall sons. Thus, a male preference for tallness in a mate would also evolve, unless there were some fairly direct counter-acting pressure.

Such a pressure is most likely to come in the form of reduced reproductive output. There are health costs of extreme stature, though these appear to apply equally to men and to women. A more specific possibility is delayed fertility among tall women. In general life-history terms, energy expended on somatic growth must be traded off against that expended on reproduction (Gadgil & Bossert 1970; Roff 1992). Sexual maturity in human females occurs only in the deceleration after the maximal growth in stature, or looked at the other way around, it is the wave of sex hormone activity associated with menarche that closes the epiphyses and effectively ends long bone growth (Sinclair & Dangerfield 1998). Sinclair & Dangerfield (1998, p. 112) suggest that, other things being equal,

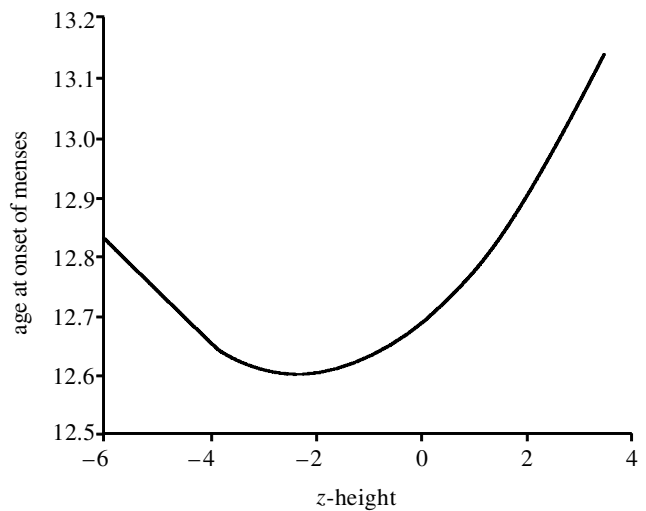


Figure 5. Regression relationship between women's height and age at onset of menstruation.

girls with late sexual maturity will be taller than those who mature early, because they are growing for longer.

The present data demonstrate such an effect. The age of onset of menstruation for the women is available from an earlier sweep of the cohort. Menarche precedes readiness to conceive by several years, but it is an important milestone on the road to fertility. Age at menarche is indeed related to height (quadratic regression: $r = 0.07$, $d.f. = 2984$, $p < 0.01$). The relationship is U-shaped (figure 5), but the upturn at the extreme of short stature may be largely due to developmental pathology. Over the range of -3 to $+3$ s.d. of height, the relationship is increasing and nearly linear. Thus, within the normal range, taller women are fertile later than their shorter peers. (This result does not appear to be an artefact of social class differences, because there is no significant association between father's social class, which is a determinant of childhood environment, and age at menarche ($F = 0.381$, $d.f. = 3046$, n.s.).)

Thus, having expended energy in growing tall is a cue that that energy has not been expended on becoming fertile early. As men's mate choice is highly orientated towards cues of fertility, it is thus no surprise that tallness has not become a cue that men make use of. Overall, these data show the explanatory value, even for the behaviour of individuals in modern populations, of an evolutionary perspective on human life history. The two sexes both follow slightly different life-history strategies themselves, and seek out slightly different life-history strategies in their partners by active, and different, mate preferences. These preferences cause sexual dimorphism to persist and appear to have endured even though the environmental context of human behaviour has changed greatly. As a result, it appears that there is still selection, albeit complex, balanced and sexually dimorphic, acting on human stature.

The National Child Development Study is carried out by the Centre for Longitudinal Studies at the Institute of Education, University of London, and the data deposited at the Data Archive at the University of Essex, from where they were obtained under licence for this study. I am grateful to Paul Preece for his assistance with data processing.

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