Original Research Article

Non-Linear Associations between Stature and Mate Choice Characteristics for American Men and their Spouses

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Objectives: Although male height is positively associated with many aspects of mate quality, average height men attain higher reproductive success in US populations. We hypothesize that this is because the advantages associated with taller stature accrue mainly from not being short, rather than from being taller than average. Lower fertility by short men may be a consequence of their and their partner's lower scores on aspects of mate quality. Taller men, although they score higher on mate quality compared to average height men, may have lower fertility because they are more likely to be paired with taller women, who are potentially less fertile.

Methods: We analyzed data from The Integrated Health Interview Series (IHIS) of the United States ($N = 165{,}606$). Segmented regression was used to examine patterns across the height continuum.

Results: On all aspects of own and partner quality, shorter men scored lower than both average height and taller men. Height more strongly predicted these aspects when moving from short to average height, than when moving from average to taller heights. Women of a given height who scored lower on mate quality also had shorter partners.

Conclusions: Shorter men faced a double disadvantage with respect to both their own mate quality and that of their spouses. Scores of taller men were only marginally higher than those of average height men, suggesting that being tall is less important than not being short. Although effect sizes were small, our results may partly explain why shorter and taller men have lower fertility than those of average stature. Am. J. Hum. Biol. 26:530–537, 2014.

Male height is positively related to many aspects of health and social status. Taller men are more likely to be more highly educated (Magnusson et al., 2006; Silventoinen et al., 2004), hold a leadership position (Stulp et al., 2012a, 2013a), have a higher income (Hakeem, 2001; Judge & Cable, 2004), be healthier (Case & Paxson, 2008; Silventoinen et al., 1999), and have lower overall mortality (The Emerging Risk Factors Collaboration, 2012; Kemkes-Grottenthaler, 2005; Sear, 2010) than their shorter counterparts. Moreover, male height has been shown to be positively related both to attractiveness (Courtiol et al., 2010a; Lynn & Shurgot, 1984; Pawlowski & Koziel, 2002; Shepperd & Strathman, 1989; Stulp et al., 2013b) and desirability during speed dating (Kurzban & Weeden, 2007; Stulp et al., 2013c). Given such findings, one might expect that the increased social status, health and attractiveness of taller men would translate into higher reproductive success, amongst other reasons given the consistent findings that taller men are preferred as partners. It came as something of a surprise, therefore, when a recent review demonstrated that men of average height experienced higher reproductive success than both taller and shorter men (Stulp et al., 2012b; 2012d). Specifically, this review revealed that, although there was substantial variation between populations in the relationship between male height and reproductive success, a curvilinear relationship was most frequently reported, and this pattern seemed to be particularly well supported in modern Western populations, most notably in the US. Two further studies in contemporary populations (published shortly after the review in Stulp, et al., 2012b) have also shown that average height men in the US (Stearns et al., 2012) and Finland (Twin sample: Silventoinen et al., 2013) fathered the greatest number of children.

How can we explain the curvilinear relationship between male height and number of offspring? In particular, why is it that taller men do relatively poorly in this respect, given that height correlates with many factors thought to contribute to both mating and reproductive success? One could argue, as many evolutionary psychologists do, that, given wide access to contraceptives and the generally accepted notion that people consciously limit their fertility, reproductive success ("counting babies": Crawford, 1993, 2000) in contemporary society has no evolutionary significance (Barkow & Burley, 1980; Symons, 1990; Tooby & Cosmides, 1997). Indeed, fertility limiting behavior is suggested to be maladaptive in some populations (Goodman et al., 2012). In other words, we could simply explain away the relationship between height and reproductive success as a quirk of modern life with little

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Additional Supporting Information may be found in the online version of this article.

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or no bearing on how natural selection has acted or continues to act, thus obviating any need to reconcile the disparity between mate preferences and reproductive outcomes. Such an explanation cannot account for why any relationship at all should exist between height and number of children, however, nor why a curvilinear relationship is so common in samples from the United States. One possible explanation, then, is that height is directly and curvilinearly related to the physiological ability to conceive (*fecundity*: e.g., sperm quality), or is related to some other trait which affects the ability to conceive. We are not aware of any evidence for this, although height has been linked to an increased risk of prostate cancer (as well as most other forms of cancer; The Emerging Risk Factors Collaboration, 2012). Diseases like prostate cancer often manifest themselves very late in life, well past the age at which most men have completed reproduction, which argues against this explanation.

In this article, we consider another hypothesis for why both taller and shorter men should experience lower reproductive success than those of average height. We suggest that a curvilinear relationship arises because of two related, but distinct, processes that act differentially on shorter and taller men. For shorter men, we suggest that lower reproductive success arises because shorter men score lower on certain mate choice characteristics, including characteristics like health and social status, known to negatively affect male mating and/or reproductive success. In addition, because shorter men are considered less desirable as mates than average height and taller men (Courtiol et al., 2010a; Stulp et al., 2013c), it is also possible that they find it more difficult to secure a high-quality mate: short men may be more likely to be paired with spouses who also score low on the relevant mate choice characteristics for a given height (as observed in Oreffice & Quintana-Domeque, 2010). Thus, there may be a double disadvantage of shorter male height with respect to fertility, and the combination of these effects may result in shorter men having fewer children than men who are taller.

In contrast, we hypothesize that the lower reproductive success of taller men may be a result of assortative mating, as taller men are more likely to be partnered to women who are taller than average, and such women may have lower fertility. Indeed, another recent review suggests that across Western societies, again particularly those in the US, taller women have lower fertility (Stulp et al., 2012c), or at least a later age at first birth (Helle, 2008; Silventoinen et al., 2013). We suggest that this reduction in female fertility accounts for the lower reproductive success of taller men, that is, in this case, the reduction in reproductive success is hypothesized to result from a reduction in female fertility that outweighs the beneficial effects of tall male stature. An important aspect of this hypothesis, then, is that the beneficial effects of tall stature are much weaker than the detrimental effects of short stature. Thus, although short men are more likely to be paired with short women, who have been demonstrated to have significantly higher reproductive success in Western societies (reviewed in Stulp et al., 2012c), the beneficial effect of assortative mating is offset by the lower quality of short men. For tall men, the beneficial effect of taller male height is offset by the detrimental effect of assortative mating to taller, and less fertile, women (whether this occurs by some physiological mechanism, or because such women tend to marry later, have a later first birth, and hence a shorter reproductive life span). Thus, the advantages to increased height accrue primarily as one moves from shorter to average heights along the height continuum, rather than when moving from average to taller heights. This is not a novel idea per se, as non-linear associations between height (or diminishing returns of height) and, for instance, measures of health (Silventoinen et al., 1999), attractiveness (Courtiol et al., 2010a; Stulp et al., 2013c), marriage prospects (Manfredini et al., 2013), cognitive function (Cinnirella & Winter, 2009), and income (Hübler, 2009) have all previously been reported; being very tall does not always provide additional benefit, and may sometimes prove detrimental. No previous studies, however, have investigated several measures simultaneously in a consistent fashion. It is also important to note that our hypothesis concerns those heights that fall within approximately 95% of all heights; we exclude from consideration those who are either extraordinarily short or tall because of the negative health (and perhaps attractiveness) implications that are related to potentially pathological growth patterns.

The relevant aspects of mate quality we assess in this study are: health, income, education, and BMI. Based on previous findings, we hypothesize that better health, higher income, and lower BMI all represent aspects of higher male mate quality, and hence potentially higher fertility. All these aspects are linked to male fertility (the number of children produced) via physical potency and/or a greater capacity for paternal investment in offspring. Good health is, *ceteris paribus*, likely to be positively associated with fertility. Similarly, although this is debated frequently, higher male income is also associated with increased fertility (e.g., Barthold et al., 2012; Hopcroft, 2006; Nettle & Pollet, 2008; Stulp et al., 2012b; Vining, 1986). In addition, a lower BMI is positively associated with health (Stommel & Schoenborn, 2010) and reproductive output (Hammoud et al., 2008; Jokela et al., 2008; Sallmén et al., 2006; Veleva et al., 2008), although, of course, very low BMI is strongly negatively related to fertility (Jokela et al., 2008; Veleva et al., 2008). Despite the fact that higher education in a partner is preferred by females (Buss, 1989; Buss et al., 1990), the effect of male education on fertility seem to vary, although the association overall is likely to be negative, or at least not positive (Barthold et al., 2012; Hopcroft, 2006; Nettle & Pollet, 2008; Stulp et al., 2012b).

For women, better health and lower BMI are also associated with higher fertility, and these characteristics are also desired by males in their partners (e.g., Buss, 1989; Tovée et al., 1998), although it should again be noted that very low BMI is negatively associated with fertility and attractiveness (e.g., Veleva et al., 2008; Tovée et al., 1998). Education is not a strongly preferred characteristic by men, and it is apparent that women value this trait more than men do, nevertheless, men prefer a partner who has achieved a level of education at least similar to their own (e.g., Buss, 1989; Buss et al., 1990). It is also apparent, however, that education has a clear negative effect on female fertility (e.g., Barthold et al., 2012; Hopcroft, 2006; Huber et al., 2010; Stulp et al., 2012c). Despite this, we view higher education as a desired mate characteristic, relative to low education. As previously mentioned, female height seems to be negatively related to fertility in contemporary Western, or at least US, populations (reviewed in Stulp et al., 2012c). Several explanations may explain this pattern. First, taller women tend to marry later and give birth to their first child at a later age than shorter women do (Byars et al., 2010; Helle, 2008; Stulp et al., 2012c; Silventoinen et al., 2013). Both of these processes may lead to reduced fertility in later life. These findings may, in turn be linked to the fact that, in contemporary populations, taller women reach menarche at a later age (Mcintyre & Kacerosky, 2011), and the subsequent effects of this on the timing of tall women's propensity to settle down and/or have children. In addition, taller women may have a later age at first birth because they are more likely to invest more heavily in their education or career, and this may lead to compromises with respect to reproduction (Begall, 2013; Deady & Law Smith, 2006). Finally, the relationship between age at first birth and height is at least partly determined by a common genetic background (Silventoinen et al., 2013; Stearns et al., 2012): some of the genes that increase stature also appear to increase the age at first birth. As a result of these associations, taller women may show lower fertility than shorter women.

Thus, in the context of this study, we predict that:

i. There will be assortative mating for height, with tall men paired to taller women more frequently than to short or average-height women.
ii. Shorter men will score lower on characteristics relating to mate quality than taller men;
iii. Shorter men will be partnered to women who score lower on characteristics relating to mate quality for a given height;
iv. The advantage of male height stems mainly from not being short, rather than from being taller than average. If this is the case, then the nature of the relationship between mate choice characteristics and height should differ when comparing taller to average height men relative to comparing average height and shorter men (i.e., in terms of the strength or direction of the relationship, or both).

Before we begin to address these above predictions, we need to express the following (and obvious) caveat. The data we use are well suited to test the above predictions, but cannot, unfortunately, directly address the association between individual quality and fecundity, nor are any measures of reproductive success available. Consequently, we view these analyses as preliminary, designed to establish the plausibility of our hypothesis or, indeed, rule it out. Our study does benefit from a very large sample, however, which allows us to assess accurately the relationship between male and female characteristics and how they change over the height continuum, using a method that is well suited to our research questions.

MATERIAL AND METHODS

Sample

We used data from The Integrated Health Interview Series (IHIS; Minnesota Population Center and State Health Access Data Assistance Center). The IHIS is a set of freely accessible data and documentation based on material originally included in the public use files of the US National Health Interview Survey (NHIS), covering 49 years of data, from 1963 to the present (https://www.ihis.us/ihis/). These data consist of records for individual persons and households from the public use files of the NHIS. The National Health Interview Survey (NHIS) is a household, face-to-face health survey, and the NHIS sample is designed to be representative of the civilian, non-institutionalized population living in the US, excluding residents in long-term care facilities, active-duty Armed Forces personnel, and US nationals living abroad (https://www.ihis.us/ihis/userNotes_sampledesign.shtml).

For the present purposes, we included only data from the survey period 1982 to 1996 as variables were measured consistently during this period ($N = 1{,}590{,}308$). Prior to 1982, many variables were assessed differently and after 1996, height and weight were not available for either the head of the household or the spouse. Hence, our sample consists of data from the 1982 wave to the 1996 wave. Only data on the household heads and their spouses (RELATE = 10 or RELATE = 20) are included in our study sample ($N = 981{,}589$), and we further restricted our sample to households in which the head of the household was married, and the spouse was present (MARSTAT=11; $N = 709{,}113$). The head of the household, or the "household reference person" (https://www.ihis.us/ihis-action/variables/RELATE#comparability_tab) is defined as the first household member of 19 years of age or older who owns or rents the sample unit (e.g. apartment, house). If no household member owned or rented the unit, the household reference person is the first household member mentioned who is 19 years of age or older. We restricted our age range to individuals between 18 and 50 years old ($N = 457{,}185$) to ensure we captured full adult height (i.e., excluding individuals that could currently be undergoing a growth spurt, or who were experiencing age-related shrinkage in height) and also to limit our sample to enduring spousal relationships; older people may choose partners using different criteria, especially if this represents a second or third marriage, and are less likely to be reproductive. Given these restrictions, 85.4% of all individuals were identified as white, 8.6% as African-American, and the remainder as either a different or unknown ethnicity. Given this imbalance and the finding that there are ethnic differences in height, we further restricted our analysis to couples where both individuals were white ($N = 390{,}499$). Subsequently, we included only those households that had a single head of household and one spouse present, who were of the opposite sex, and for whom there were identical values for overall household income ($N = 354{,}450$ individuals in 177,225 households).

For individual characteristics, we included the following variables: age, height, weight, education, and health. Height (without shoes) was self-reported and was measured in inches, and weight (without shoes and clothes) was measured in pounds. To achieve comparability across all years, IHIS advises that analyses should be restricted to persons whose height fell within the range from 59 to 76 inches, and whose weight fell within 100–285 pounds. We therefore excluded individuals who fell outside these ranges (thereby also restricting our sample to only those couples for which height and weight were available), leaving a final total of 331,212 individuals, and thus 165,606 married couples for analyses.

We used height and weight to calculate BMI, as this is a more accurate measure of body mass independent of height. Education was measured as the respondent's highest grade of schooling completed, in single grades or

TABLE 1. Descriptive statistics of the sample

	Men		Spouse	
	Mean ± SD / %	*N*	Mean ± SD / %	*N*
Age (years)	36.36 ± 7.64	165,606	34.25 ± 7.58	165,606
Height (cm)	178.47 ± 7.03	165,606	164.26 ± 6.57	165,606
Height (inch)	70.26 ± 2.78	165,606	64.67 ± 2.59	165,606
BMI (kg/m^2)	25.98 ± 3.70	165,606	23.64 ± 4.54	165,606
Education	14.29 ± 2.78	165,108	14.05 ± 2.49	165,264
Health		165,355		165,276
Poor	1.2%	1,981	1.0%	1,581
Fair	3.9%	6,505	4.5%	7,475
Good	17.5%	28,991	22.0%	36,430
Very good	30.7%	50,753	32.7%	54,013
Excellent	46.6%	77,125	39.8%	65,777
Household income		148,193		
0–5k$	1.2%	1,840		
5k–10k$	3.3%	4,941		
10k–15k$	6.0%	8,867		
15k–20k$	8.9%	13,135		
20k–25k$	9.8%	14,573		
25k–30k$	10.5%	15,545		
30k–35k$	11.0%	16,334		
35k–40k$	8.8%	13,040		
40k–45k$	8.2%	12,147		
45k–50k$	6.9%	10,238		
>50k$	25.3%	37,533		

years of college in 19 different categories ("HIGRADE1"): 1 = "Never attended kindergarten", 2–13 = "Grade 2"– "Grade 12", 14–19 = "College: 1 year"– "College: 6 years or more". Health was self-reported and consisted of five categories ("Poor", "Fair", "Good", "Very good", and "Excellent"). Household income was originally binned in 27 categories, with varying bin sizes. Therefore, we divided household income ("INCFAMR68ON") into 11 categories, 10 bins of $5000, and a bin of >$50.000. We ranked these bins from 1 to 11. Year of birth was calculated from age and survey year. See Table 1 for descriptive statistics and sample sizes available for all analyses.

Analysis

To examine how individual characteristics predicted own and spousal characteristics, we first performed General Linear Models including male height and height^2, along with males' year of birth (to account for any secular trends in the data). When a significant effect of height^2 was found (which was always the case; Table 2), we determined the maximum or minimum value of the effect of height [-(estimate for height)/(2 × estimate for height^2)]. We used this value as the starting value for the segmented regression (or piecewise regression). A segmented regression tests whether there is any difference in the linear relationship between an independent variable and a dependent variable over the interval of the independent variable (i.e., can one detect any significant change in the slope of the relationship as the value of the independent variable increases). More specifically, the independent variable (in our analyses, height) is partitioned into intervals, and a straight line is fitted to each interval. With this method, we gain the following information: (i) the breakpoint (± SE), which is the point at which the slope of the linear relationship changes, (ii) the slopes of the two fitted lines, plus the 95% confidence interval, and (iii) an R^2 for the total model. We use this method to test for differences in the slope of the relationship between height and our measures of mate choice characteristics as one moves up the height continuum. That is, for each dependent measure, we tested whether the slope moving from short to average height was significantly different from the slope moving from average height to the tallest height in our sample. Year of birth was also included in these analyses. Given the original measurements were in inches, our analyses also used height in inches. For graphical purposes and descriptive statistics, we transformed inches into centimeters. Although height varies across time and across ages, standardizing height per 5 year birth cohort led to very similar estimates as those obtained using non-standardized height (correlation height and standardized height $r > 0.99$ for both males and females), which is why we chose to use the original height values.

As dependent variables, we used the male's own characteristics (education, health, BMI, and household income), and his spousal characteristics (education, health, BMI, and height). We acknowledge that it could be considered somewhat dubious to use ordinary least squares regression methods for measures that, because of their categorical nature, are not always normally distributed (i.e., education, health, and income). However, we chose to do so for several reasons. First, no transformation would render the aforementioned variables more normally distributed, nor are the distributions suitable for Generalized Linear Methods. Additionally, the problems of normality of the dependent variables hold for both shorter and taller men; given that we are interested in the comparison between these men, any bias that affects these classes of men equally should not therefore affect the outcome and interpretation of our analyses. Finally and most importantly, graphical representations of the data were very much in line with our statistical results, suggesting that we have not inaccurately portrayed the actual relationships that exist (see Supporting Information Figs. S1 and S2). Thus, although some of our measures may suffer

TABLE 2. Linear regression estimates and segmented regression estimates [B (SE)] for the effect of male height on own and spousal characteristics, while controlling for male year of birth

	Own traits				Spousal traits			
	Education	Health	BMI	Income	Education	Health	BMI	Height
N	165,108	165,355	165,606	148,193	165,264	165,276	165,606	165,606
Partial r^a	0.21	0.10	−0.08	0.16	0.20	0.09	−0.09	0.20
Linear regression								
Intercept	−71.58 (3.52)	−36.97 (1.21)	202.87 (4.77)	23.32 (3.90)	−97.71 (3.16)	−22.49 (1.21)	254.78 (5.85)	−16.80 (3.29)
Year of birth	−0.0180 (0.00079)	0.0110 (0.00027)	−0.0382 (0.00107)	−0.0567 (0.00087)	0.0017 (0.00071)	0.0040 (0.00027)	−0.00440 (0.00131)	0.0104 (0.00074)
Height (inch)	3.260 (0.089)	0.529 (0.030)	−2.834 (0.121)	2.555 (0.099)	2.925 (0.080)	0.508 (0.031)	−4.021 (0.148)	1.572 (0.083)
Height^2	−0.022 (0.00064)	−0.0036 (0.00022)	0.0196 (0.00086)	−0.0171 (0.00070)	−0.0197 (0.00057)	−0.0034 (0.00022)	0.0278 (0.00106)	−0.0099 (0.00059)
$R^{2\,b}$	0.0527	0.0207	0.0159	0.0550	0.0475	0.0115	0.0184	0.0410
Optimum^c	74.57	74.43	72.37	74.62	74.42	74.50	72.45	79.00^d
Segmented regression								
Breakpoint	69.51 (0.077)	69.80 (0.171)	67.21 (0.108)	69.99 (0.113)	69.44 (0.077)	69.99 (0.179)	69.49 (0.104)	69.25 (0.150)
Slope before	0.381 (0.0066)	0.058 (0.0023)	−0.390 (0.0161)	0.284 (0.0074)	0.339 (0.0060)	0.056 (0.0023)	−0.361 (0.0110)	0.270 (0.0062)
Slope after	0.0726 (0.0052)	0.0095 (0.0018)	−0.0417 (0.0048)	0.0420 (0.0057)	0.0620 (0.0047)	0.0079 (0.0018)	0.0187 (0.0086)	0.1238 (0.0049)
Difference magnitude^e	5.26	6.12	9.35	6.77	5.47	7.06	−19.28	2.18
$R^{2\,b}$	0.0538	0.0209	0.0160	0.0560	0.0486	0.0118	0.0187	0.0414

All estimates (highly) significant. For *t*-values, parameter estimates can be divided by the standard error. The degrees of freedom for the *t*-value are the sample size minus 4 for the linear regression and minus 5 for the segmented regression.

[a] Partial Pearson *r* between height and the dependent variable, with the effect of male year of birth partialled out.

[b] Adjusted R^2.

[c] Optimum was used as starting value for segmented regression [-(estimate for height)/(2 × estimate for height^2)].

[d] Because this optimum fell outside the height range, we used the maximum value of male height as a starting value for the segmented regression.

[e] Slope before divided by slope after.

from non-normality to some degree, we believe our methods are justified. Having said this, our estimates should be treated with a degree of caution.

All analyses were performed in R (R Development Core Team, 2008; version 2.15.3); segmented regressions were performed using the "segmented" package.

RESULTS

Is there assortative mating for height?

Male height was positively correlated with spousal height ($r = 0.20$; $df = 165603$; $P < 0.0001$; partialling out the effect of male year of birth; Table 2), indicating assortative mating. Increasing one inch in male height led to a predicted increase of 0.18 inch in partner height. Although this constitutes clear evidence for assortative mating, the correlation coefficient was very low (albeit very much in line with previous research; Silventoinen et al., 2003; Spuhler, 1982; Stulp et al., 2013d).

Do shorter men score lower on mate choice characteristics than taller men?

Male height was curvilinearly related to all our dependent measures (Table 2), with the optimum of this curvilinear pattern sitting at a value around or above average male height (controlling for male birth year in all our analyses). Short men were less educated, less healthy, had a higher BMI, and lower household income than taller men (Fig. 1A; Supporting Information Fig. S1).

Are female scores on mate choice characteristics associated with male partner height?

Again, controlling for male year of birth, we find that shorter men had less educated, less healthy wives, with a higher BMI (Fig. 1B; Supporting Information Fig. S2). Furthermore, a linear regression revealed that, when controlling for female height, less educated, less healthy, and women with a higher BMI had shorter husbands. In other words, women of a given height who were paired with shorter partners also tended to be less healthy, less educated, and with a higher BMI than women of the same height who were paired with taller partners (Table 3).

Does the nature of the relationship between height versus own and spousal characteristics shift across the height continuum?

We used the optima from the curvilinear effect of height to perform segmented regressions. A strikingly similar pattern was observed for all variables: the effect of height (controlling for male year of birth) on the dependent variable was much stronger when moving from shorter heights to the breakpoint (which was very close to average male height in most cases; Table 2; Fig. 1), than when moving from the breakpoint to taller heights. The slopes before and after the breakpoint were all significantly different from zero, and these slopes were significantly different from each other in all analyses (95% confidence intervals of the slopes never overlapped) (Table 2).

The largest difference in slope was observed for the effect of male height on spousal BMI: before the breakpoint an increase of one inch in height decreased spousal BMI by 0.36 SD, whereas above the breakpoint, a one inch increase in height increased spousal BMI by only 0.02 SD (a 20 fold difference in magnitude). The smallest difference in magnitude was observed for spousal height

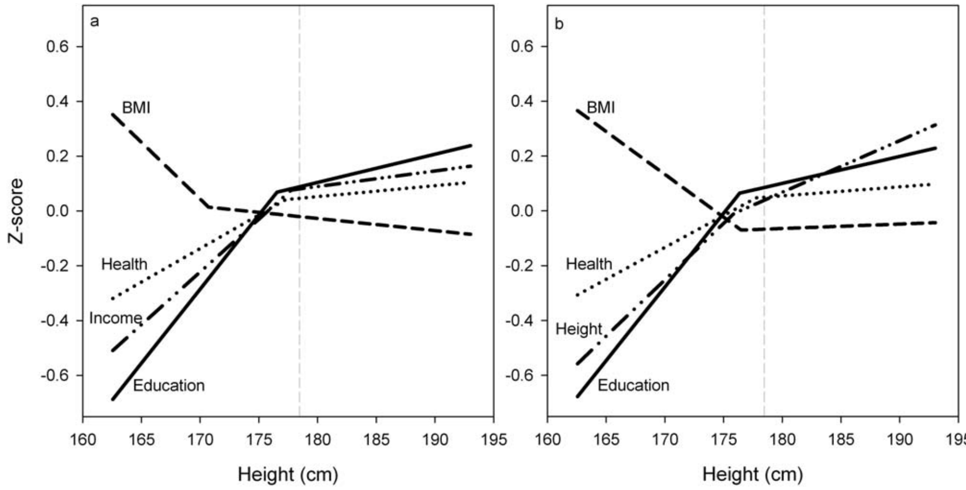

Fig. 1. The effect of male height on (a) one's own education, BMI, health, and household income and (b) spousal education, BMI, health, and height. Lines are predictions from segmented regressions (see text and Table 2). The vertical line reflects average male height. All predictions were standardized (i.e., the mean subtracted from individual values divided by SD) for comparison. The data is plotted for the range 162.56–193.04 cm (64–76 inch).

TABLE 3. Linear regression estimates (B ± SE) for the effect of female height, education, BMI, and health on spousal (male) height

	B ± SE	B
Constant	56.23 (0.178)	
Height	0.177 (0.003)	0.166
Education	0.183 (0.003)	0.164
BMI	−0.019 (0.001)	−0.031
Health	0.110 (0.007)	0.037
Adjusted R^2	0.072	
N	164,937	

All estimates (highly) significant. For t-values, parameter estimates can be divided by the standard error. The degrees of freedom for the t-value are the sample size minus 5.

(a twofold difference in magnitude). For all analyses, the adjusted R^2 was higher for the segmented regression than for the linear regression using height and height^2 (although the differences were very small; Table 2), suggesting that two separate regression lines fitted through the data are a more accurate description of the data than a single quadratic fit.

DISCUSSION

In line with our predictions, our results suggest that shorter men face a double disadvantage: shorter stature was significantly associated with lower scores on several mate choice characteristics, and shorter men were also significantly more likely to be paired to women who also scored low on these same characteristics. These two findings may, therefore, explain why shorter men have lower reproductive success than men of average height. These effects occur despite shorter men having the advantage of being paired to shorter women, as evidenced by assortative mating (which, all else being equal, should increase reproductive success in industrial societies, since shorter women have higher fertility: Stulp et al., 2012c)

We also found that the differences between taller men and those of average height were much less marked than those between average height and short men. As predicted, taller men were not markedly superior in measures of "quality" compared to men of average height (indeed in the case of one characteristic, BMI, they were of slightly lower "quality" than average height men—given, of course, that BMI measures male quality in some way). Our segmented regression analysis revealed that, for all our measures of mate quality, the "breakpoint"— the point that describes where the biggest change in strength of relationship occurs—was close to average male height. The advantage to height therefore seems to accrue from not being very much shorter than average, rather than being much taller than average. In other words, when compared to men of average height, the penalties of shorter stature are substantially larger than the gains for taller stature, in terms of both own and spousal characteristics.

Finally, and again in line with our predictions, taller men were more likely to be paired with women who were taller than average. The finding that taller men are paired to taller women, and that their own apparent quality was not much greater than that of average height men, supports our hypothesis to explain why taller men have fewer children than men of average height. Indeed, in the case of tall men, the negative effect of taller spousal height on reproductive success may offset the minor positive effect of their own higher quality, resulting in lower reproductive success compared to men of average height.

It is crucial to note that the effect sizes in our analyses were very small, and our results must be treated with some caution: explaining only 2–5% of the variance in a relationship that itself accounts for only 1% of the overall variance in reproductive success represents a major limitation of our study. Indeed, on the basis of these results, we cannot conclude that male quality and assortative mating underlie the observed differences in reproductive success along the height continuum: it is unclear whether an effect size this small could exert any discernible influence on reproductive success. Having said this, our sample incorporated only married individuals who resided in the same household, that is, couples in a currently stable relationship. This is pertinent because demographic datasets are often biased with respect to the representation of particular groups. In particular, unmarried or previously married men and women are often underrepresented and/or have higher drop-out rates (e.g., Rendall et al., 1999). This renders our test a conservative one given the possibility that shorter men potentially are less likely to be married or in a stable relationship, and hence underrepresented in the sample. Clearly, more stringent empirical tests are needed to assess whether male quality and assortative mating can account for observed reproductive differentials with respect to height. Ideally, we would examine how both spousal heights within couples simultaneously affect the number of surviving children, in order to assess the impact of an individual's own height on reproductive success, independently of spousal height. What our data do suggest, however, is that further analyses of this kind are well worth pursuing.

Although assortative mating was present in our sample, the slope of the relationship above the breakpoint (from average height to taller men) was shallower than the slope of the relationship between short and average height men. That is, the strength of assortative mating declines as one move along the height continuum. This suggests that, while women prefer men who are taller than themselves (male-taller norm; Gillis & Avis, 1980; Pierce, 1996), but not too tall (the male-not-too-tall norm; Stulp et al., 2013d), the former norm is more strictly enforced than the latter (in line with Stulp et al., 2013d). Thus, women apparently possess a strong preference for men to be taller than themselves, but they feel less strongly about men who are very much taller than them. This might result in shorter men pairing up with women who are shorter than themselves but only by a small margin, by virtue of the fact that there will be relatively few women in the population who are substantially shorter than the shortest men. Taller men, on the other hand, will always be taller than a majority of the female population. The male-taller norm is therefore easily satisfied, and the male-not-too-tall-norm should then be of more concern to women. The less strict enforcing by women of the male-not-too-tall norm may therefore result in larger variation in partner height for taller men. Indeed, if we examine heights that lie within two standard deviations above and below the mean (i.e., between 64 and 76 inches; excluding only 0.6% of the data), we find a strong positive correlation between male height and the standard deviation of spousal height ($r = 0.935$; $N = 13$ (number of inches from 64 to 76 inch); $P < 0.0001$), suggesting that shorter men are indeed matched with spouses who are more similar in height than are the spouses of taller men. There is, however, still positive assortment for height among men who are taller than average, suggesting that women show a clear tendency to prefer men who are not too much taller than they are. In addition, male preferences must factor in here: it has been shown that men tend to prefer and choose much smaller height differentials than women do (Courtiol et al., 2010a; Pawlowski, 2003; Stulp et al., 2013b, 2013c). These findings cannot, however, explain why taller men do not have much taller women as wives as a result of this preference for smaller height differentials by males. Instead, this could be taken as further evidence for the finding that men simply value height less in a mate than women do. Overall, these findings suggest that preference rules vary in their strength, both within and between the sexes, and are therefore enforced differentially, creating different patterns of assortment for stature across the height continuum.

Perhaps the most reasonable conclusion to draw from our analyses is that, despite identifying clear differences in relevant mate choice characteristics between short men and those of average height or taller, the very small effect sizes emphasize the long and convoluted path from attractiveness ratings (mate preferences) to reproductive success. While tall men are consistently favored in preference studies, and short men are disfavored, our results indicate that a great deal of variety exists in the composition of actual pairs with respect to both height and other aspects of mate quality. These are findings that echo those of previous studies that have investigated actual pairing (Courtiol et al., 2010b; Stulp et al., 2013c). Aspects of mutual mate choice not captured by the kinds of measures included here, such as personality, recreational interests, sense of humor, sexual compatibility, and many other kinds of idiosyncratic preferences, play a strong and important role in the establishment of enduring partnerships. It is perhaps not surprising that the effects shown here are so weak. Indeed, given the many intersecting dimensions along which our mating preferences are formed, combined with the vagaries of mutual mate choice, it is surprising (and significant) that height actually exerts any measurable influence on the mating process at all, let alone on reproductive success. It is clear that the issue of how fertility differentials arise in modern industrial societies is a complex matter. Genuine progress on this front will require detailed investigation both at the individual level, where we can examine how life history events and reproductive trajectories differ in relation to our variables of interest, as well as those at the population level, where we have the sample sizes needed to reliably detect the existence of such differentials in the first place.

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