

# Reports

## How Well Does Paternity Confidence Match Actual Paternity?

Evidence from Worldwide Nonpaternity Rates

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Evolutionary theory predicts that males will provide less parental investment for putative offspring who are unlikely to be their actual offspring. Cross-culturally, paternity confidence (a man's assessment of the likelihood that he is the father of a putative child) is positively associated with men's involvement with children and with investment or inheritance from paternal kin. A survey of 67 studies reporting nonpaternity suggests that for men with high paternity confidence rates of nonpaternity are (excluding studies of unknown methodology) typically 1.9%, substantially less than the typical rates of 10% or higher cited by many researchers. Further cross-cultural investigation of the relationship between paternity and paternity confidence is warranted.

The issue of paternity—whether a man really is the biological father of his supposed children—has long been a topic of interest to anthropologists. Evolutionary theory predicts that males will provide less parental investment for putative genetic offspring who are unlikely to be their actual offspring (e.g., Alexander 1974; Trivers 1972). Actual genetic paternity may differ from paternity confidence (a man's assessment of the likelihood that he is the father of a putative child), which must be assessed through indirect cues such as mate fidelity or child resemblance. There is great variation across cultures in beliefs about paternity (e.g., Beckerman et al. 1998; Hrdy 2000; Levine 1987), but cross-culturally, paternity confidence is positively associated with men's involvement with children and with investment or inheritance from paternal kin (e.g., Flinn 1981; Gaulin and Schlegel 1980; Greene 1979; Hartung 1985).

This paper draws on 67 studies reporting nonpaternity to examine the relationship between paternity confidence and actual paternity and to look for global variation in this relationship. I test the hypothesis that men with high paternity confidence will have higher rates of actual paternity than men with low paternity confidence by comparing nonpaternity

rates from two groups of men: one biased toward high paternity confidence and the other toward low paternity confidence. The relative frequencies of men with high and low paternity confidence are unknown, which makes it difficult to estimate true nonpaternity rates for human societies.

### Nonpaternity in Cross-Cultural Perspective

Nonpaternity rates in human societies are often cited as being 10% or greater in general populations (e.g., Alfred 2002; Cervino and Hill 2000; Stewart 1989), though little or no empirical support is generally provided for this assertion (MacIntyre and Sooman 1991). Baker and Bellis (1995) report a worldwide median nonpaternity rate of 9% from a sample of ten studies. While little is known about global variation in nonpaternity, even less is known about cross-cultural patterns of paternity confidence. Gaulin and Schlegel (1980) used three variables measuring degree of female sexual promiscuity in 135 societies to create a dichotomous measure of paternity confidence and estimated that only 55% of societies in their sample have high paternity confidence. Huber et al. (2004) used four measures of extramarital sexual activity from 57 cultures to create a 16-level measure of paternity confidence. Their results indicate that 63% of societies have paternity confidence levels at or above the median. Thus, while paternity confidence is high for many societies, a substantial minority appear to have reduced levels of paternity confidence.

In recent years, the determination of nonpaternity has become a science. Modern paternity tests cannot prove paternity; instead they prove nonpaternity by excluding men whose genotype is incompatible with that of the child in question (Pena and Chakraborty 1994; Wilson 1987). Failure to exclude a man as the father can be taken as proof of paternity if the probability of excluding nonfathers is extremely high; the probability that a man is likely to be the father is calculated using Bayesian logic, based on assumptions of the frequencies of the genotypes under consideration in the general population (for further details see Mickey, Gjertson, and Terasaki 1986; Pena and Chakraborty 1994). Contemporary paternity tests, which use DNA polymorphisms to determine nonpaternity, have probabilities of exclusion in excess of 99.99%, so that out of 10,000 paternity tests the true nonfather will be excluded as a potential father 9,999 times (Helminen et al. 1988; Jeffreys, Turner, and Debenham 1991; Pena and Chakraborty 1994). Older (pre-1985) paternity tests, based on blood type or HLA antigens, had lower probabilities of exclusion, ranging from 18% (using only the ABO blood types) up to 95% or more. A lower probability of exclusion means that nonpaternity will not be established for some nonfathers (for example, a man may have a blood type that is compatible with being the father of the child even though he is not the father). Many older studies therefore report two nonpaternity rates: the observed nonpaternity (the proportion of men excluded in the study) and the actual nonpaternity

Table 1. Nonpaternity Rates (%) When Paternity Confidence Is Relatively High

Population	Actual	Observed	Probability of Exclusion	Sample Size	Source
Sephardic Kohanim (Jewish priests)	0.4	—	—	24	Boster et al. (1999)
United States	0.8	—	—	496	Broman (1999)
Switzerland	0.83	—	—	1,607	Sasse et al. (1994)
Ashkenazic Kohanim (Jewish priests)	1.2	—	—	44	Boster et al. (1999)
Canada (Quebec)	1.2	—	—	42	Heyer et al. (1997)
United Kingdom	1.3	—	—	48	Sykes and Irven (2000)
United Kingdom	1.35	—	—	521	Brock and Shrimpton (1991)
United States (Michigan), white	1.49	0.28	18.8	1,417	Schacht and Gershowitz (1963)
Iceland	1.49	—	—	not stated	Helgason et al. (2003)
United Kingdom	1.59	—	—	756	Chataway et al. (1999)
Sweden	1.6	—	—	63	Böök (1950)
United States (California), white	2.1	0.8	38.1	6,960	Peritz and Rust (1972)
United States (Hawaii)	2.3	—	—	2,839	Ashton (1980)
United States	2.8	0.5	18.0	200	Wiener, Gordon, and Handman (1949)
France	2.8	—	—	362	Le Roux et al. (1992)
Mexico	2.9	2.3	80.3	217	Peñaloza et al. (1986)
United Kingdom (West London)	3.7	0.7	18.0	2,596	Edwards (1957)
Canada	4.0	—	—	25	Poon et al. (1993)
France	6.9–9.4	—	94.4	266–361	Salmon, Seger and Salmon (1980)
Brazil/Venezuela (Yanomamo)	9.1	6.1	64.0	132	Neel and Weiss (1975)
United States (Michigan), black	10.1	1.91	18.9	523	Schacht and Gershowitz (1963)
Mexico (Nuevo León)	11.8	8.1	64.0	396	Cerda-Flores et al. (1999)

Note: Probability of exclusion is unstated if it is greater than or equal to 95% or is not applicable.

(the proportion of men who *should have been* excluded, not all of them because of limitations of the test). For example, if the probability of exclusion in a study is 50% and the study finds a 5% nonpaternity rate in the sample, then the actual nonpaternity rate is 10%.

## Methods

For the present study, published data on nonpaternity rates were gathered through extensive literature searches, using on-line databases, bibliographies, and journal indices, resulting in a sample of 67 nonpaternity rates. While this list cannot be considered complete, it is the most extensive published list of nonpaternity rates assembled to date, far exceeding pre-existing lists (e.g., Baker and Bellis 1995; James 1993; Lucassen and Parker 2001; MacIntyre and Sooman 1991; Sasse et al. 1994).

The measures of nonpaternity used in this study were estimated in many different ways. Because older methods of establishing nonpaternity had lower probabilities of exclusion (i.e., were less likely to detect nonpaternity), the proportion of men actually excluded in older (pre-1985) papers is always less than the number of nonfathers in the sample who should have been excluded. Most researchers adjust for this accordingly, presenting both the observed nonpaternity and the actual (adjusted) nonpaternity; in a few cases, actual nonpaternity was not stated, and I calculated actual nonpaternity from the stated probability of exclusion. More recent references, with greater probabilities of exclusion (greater than 95% and typically exceeding 99.99%), do not distinguish be-

tween observed and actual nonpaternity, as the difference is minimal. In a few cases where nonpaternity is estimated through other methodologies (for example, Mendelian inconsistencies), there is no difference between observed and actual nonpaternity. Where possible, the actual nonpaternity rate will be used for the analysis.

On the basis of the level of presumed paternity confidence within each group, the data set is divided into three groups: (1) men with relatively high paternity confidence, (2) men with relatively low paternity confidence, and (3) men whose paternity confidence is unknown.

1. *High paternity confidence.* This group includes 22 data points from genetic studies or other sources that are likely to bias the sample toward high paternity confidence (see table 1). None of these studies come from random samples. The nature of these studies (especially the genetic and lineage studies) will bias the samples toward men with high paternity confidence because men who do not believe they have fathered their putative children will be less likely to participate in the research. Most of these studies include mother/father/child trios, and many contain primarily or exclusively married couples. Since men in marriages are likely to have higher paternity confidence than men who father children outside of marriage (Anderson, Kaplan, and Lancaster 2005a), this will further bias the sample toward men with high paternity confidence. Some men in this sample undoubtedly do not have high paternity confidence; additionally, the studies may have included covert adoptions, misidentified stepchildren, etc., for whom paternity confidence is zero. Overall, however,

these studies are likely to include men whose paternity confidence is relatively high.

2. *Low paternity confidence.* All of the 31 data points in this group come from studies of disputed paternity (for example, from paternity testing laboratories) (see table 2). The men in this sample were sufficiently doubtful of their paternity to participate in laboratory tests to determine if they were the fathers of their putative children; thus, this sample is categorized as having low paternity confidence.

3. *Unknown paternity confidence.* This group contains 14 data points for which no conclusion can be drawn regarding the paternity confidence of the men involved (see table 3). Many are from unpublished or secondhand sources, and therefore we do not know whether the reported nonpaternity reflects observed or actual nonpaternity or if the rates have been adjusted for laboratory error.<sup>1</sup> One study (Baker and Bellis 1990) estimates nonpaternity through women's reports

1. The unpublished !Kung nonpaternity rate reported in Trivers (1972) has subsequently been suggested to be due almost entirely to laboratory error, since the rate of nonmaternity in the sample was approximately the same (Howell 2000; Smith 1984).

of sexual behavior; it presents no data on whether their partners had high or low paternity confidence in any resulting pregnancies.

It could be argued that since the sample whose paternity confidence is unknown is unlikely to be composed of men actively disputing paternity, the cases in table 3 should be added to those of the men with high paternity confidence (table 1). This will also make my estimates of nonpaternity more comparable to those of previous studies (e.g., Baker and Bellis 1995). The analyses will first examine each group separately and then combine the high- and unknown-paternity-confidence groups into a single group.

The data presented in tables 1–3 allow us to examine whether there is worldwide variation in nonpaternity rates by men's paternity-confidence level. The data were organized geographically into three groups: United States and Canada ( $N = 27$ ), Europe ( $N = 26$ ), and elsewhere ( $N = 14$ ). The "elsewhere" category is extremely heterogeneous, as it encompasses samples from South and Central America, Africa, Israel and India; however, none of these regions have sufficient sample sizes to stand alone as separate categories. While it would

Table 2. Nonpaternity Rates (%) from Paternity Testing Laboratories

Population	Actual	Observed	Probability of Exclusion	Sample Size	Source
Russia	14.3	–	–	21	Molyaka et al. (1997)
Finland <sup>a</sup>	15.2	14.3	94.0	35	Helminen et al. (1992)
United Kingdom	16.6	–	–	1,702	Jeffreys, Turner, and Debenham (1991)
Germany	16.8	–	–	256	Krawczak et al. (1993)
Brazil (Belo Horizonte)	22.0	–	–	200	Pena et al. (1993)
South Africa, white	22.4	–	–	264	Du Toit et al. (1989)
United States (Cleveland)	23.9	12.0	50.0	67	Marsters (1957)
United States (Los Angeles), white	24.9	–	–	1,393	Mickey, Gjertson, and Terasaki (1986)
United States	25.0	–	–	1,000	Terasaki (1978)
United States	25.2	–	–	2,500	Houtz et al. (1982)
United States	26.0	–	–	50	Alford et al. (1994)
Portugal	27.7	–	–	83	Geada et al. (2000)
United States (New York City)	28.7	14.3	50.0	300	Sussman (1956)
United States (Baltimore)	29.0	–	–	124	James (1993)
United States (New York City)	29.4	–	–	102	Baird et al. (1986)
Portugal	29.8	–	–	790	Geada et al. (2000)
South Africa, Cape Malay	30.5	–	–	59	Du Toit et al. (1989)
United States (New York City), black <sup>a</sup>	30.6	15.3	50.0	98	Wiener (1950)
United States (Cleveland)	32.0	16.0	50.0	200	Marsters (1957)
United States (New York City), white <sup>a</sup>	34.4	17.2	50.0	425	Wiener (1950)
Finland	34.6	–	–	26	Helminen et al. (1988)
United States (Illinois)	37.0	–	–	753	Strom et al. (1996)
France (Paris)	38.1	–	–	543	Rouger and van Huffel (1996)
Sweden	38.7	33.5	86.5	5,018	Valentin (1980)
South Africa, Cape Coloured	40.1	–	–	1,156	Du Toit et al. (1989)
South Africa, black	41.1	–	–	645	Du Toit et al. (1989)
United States	42.0	21.0	50.0	100	Sussman (1954)
Italy	45.0	–	–	31	Gasparini et al. (1991)
United States (Illinois)	53.0	–	–	37	Strom et al. (1996)
Sweden <sup>a</sup>	55.0	8.4	15.4	142	Hirschfeld and Heiken (1963)
United States <sup>a</sup>	55.6	27.8	50.0	108	Unger (1953)

<sup>a</sup>Actual nonpaternity not calculated in the original paper.

Table 3. Nonpaternity Rates (%) When Paternity Confidence Is Unknown

Population	Nonpaternity	Probability of Exclusion	Sample Size	Source
Southern Africa (!Kung)	2.0	—	not stated	Harpending (unpublished), cited in Trivers (1972)
United Kingdom	4.8	—	21	Shields (unpublished), cited in Scharfetter (1978)
England	6.9–13.8	—	2,708	Baker and Bellis (1990)
United States (rural Michigan)	ca. 10	—	not stated	Chagnon (unpublished), cited in Smith (1984)
Munich and Copenhagen	at least 10	—	not stated	unpublished; cited by Ritz in Grünfeld (1985)
United States	10–30	—	not stated	Reed (unpublished), cited in Allison (1996)
Italy	13.2	—	38	Hirsch and Vetta (1978)
India	~15.3	—	not stated	Meisner (1999), cited in Cervino and Hill (2000)
United States	18.0	50.0	67	Sussman and Schatikin (1957)
United Kingdom (Liverpool)	20–30	—	not stated	McLaren (unpublished), cited in Cohen (1977)
United States (Michigan), black	20.1	18.75	265	Wiener (1966)
United Kingdom (Southwestern England)	30	—	200–300	unpublished, cited in Philipp (1973)
Africa	~30	—	not stated	Ruwende (1996), cited in Cervino and Hill (2000)
India (Vishakapatnam)	32	—	not stated	Meisner (1999), cited in Cervino and Hill (2000)

Note: Probability of exclusion is unstated if it is greater than or equal to 95% or is not applicable.

be interesting to examine paternity by ethnic group, the data do not allow this.

Because the data are not normally distributed, comparisons between groups will be made using the nonparametric Wilcoxon rank-sum test. All analyses were done using STATA SE v. 8.2. The actual nonpaternity rates used for analysis are uncorrelated with the sample size, probability of exclusion, or year of publication associated with each study.

## Results

The median nonpaternity rate for the high-paternity-confidence sample is 1.7% (range: 0.4–11.8), while median nonpaternity for the low-paternity-confidence sample is 29.8% (range: 14.3–55.6). The median nonpaternity rates for these two groups are significantly different (Wilcoxon sign-rank test,  $z = (-6.156, p < 0.0001)$ ). The median nonpaternity of men whose paternity confidence is unknown is 16.7% (range: 2.0–32.0). This is significantly greater than that of the high-paternity-confidence sample (Wilcoxon sign-rank test,  $z = (-4.382, p < 0.0001)$ ) and significantly lower than that of the low-paternity-confidence sample (Wilcoxon sign-rank test,  $z = 3.531, p = 0.0004$ ). When the high- and unknown-paternity-confidence samples are combined, the median nonpaternity is 3.3% (range: 0.4–32.0). This is significantly less than median nonpaternity for men with low paternity confidence (Wilcoxon sign-rank test,  $z = -6.099, p < 0.0001$ ).

Figure 1 shows median nonpaternity by geographic location for the high-paternity-confidence, combined high- and unknown-paternity-confidence, and low-paternity-confidence samples. Within each paternity-confidence group, there is no significant geographic variation in the median values of nonpaternity (Wilcoxon sign-rank tests, results not shown,  $p > 0.51$  for every comparison). In other words, men with high paternity confidence have similar levels of actual paternity in the United States and Canada, Europe, and the rest of the

world; the same is true for the other two paternity-confidence groups. However, for all three geographic locations nonpaternity is significantly greater in the low-paternity-confidence sample than in the high-paternity-confidence sample (Wilcoxon sign-rank tests: United States and Canada  $z = -3.873, p = 0.0001$ ; Europe  $z = -3.761, p = 0.0002$ ; elsewhere  $z = -2.611, p = 0.0090$ ;) and in the combined high/unknown-paternity-confidence sample (Wilcoxon sign-rank tests: United States and Canada  $z = -4.392, p < 0.0001$ ; Europe  $z = -3.763, p = 0.0002$ ; elsewhere  $z = -2.333, p = 0.0196$ ).

## Conclusion

This survey of published estimates of nonpaternity suggests that for men with high paternity confidence, nonpaternity rates are typically 1.7% (if we exclude studies of unknown methodology) to 3.3% (if we include such studies). These figures are substantially lower than the “typical” nonpaternity rate of 10% or higher cited by many researchers, often without substantiation (e.g., Alfred 2002; Cervino and Hill 2000; Stewart 1989), or the median worldwide nonpaternity rate of 9% reported by Baker and Bellis (1995).

Men who have low paternity confidence and have chosen to challenge their paternity through laboratory testing are much less likely than men with high paternity confidence to be the fathers of their putative children. Although these men presumably have lower paternity confidence than men who do not seek paternity tests, this group is heterogeneous; some men may be virtually certain that the putative child is not theirs, while others may simply have sufficient doubts to warrant testing. Most of these men are in fact the fathers of their putative genetic children; only 29.8% could be excluded as biological fathers of the children in question.

The results of this study raise many questions. What is the true level of nonpaternity in any particular human popula-

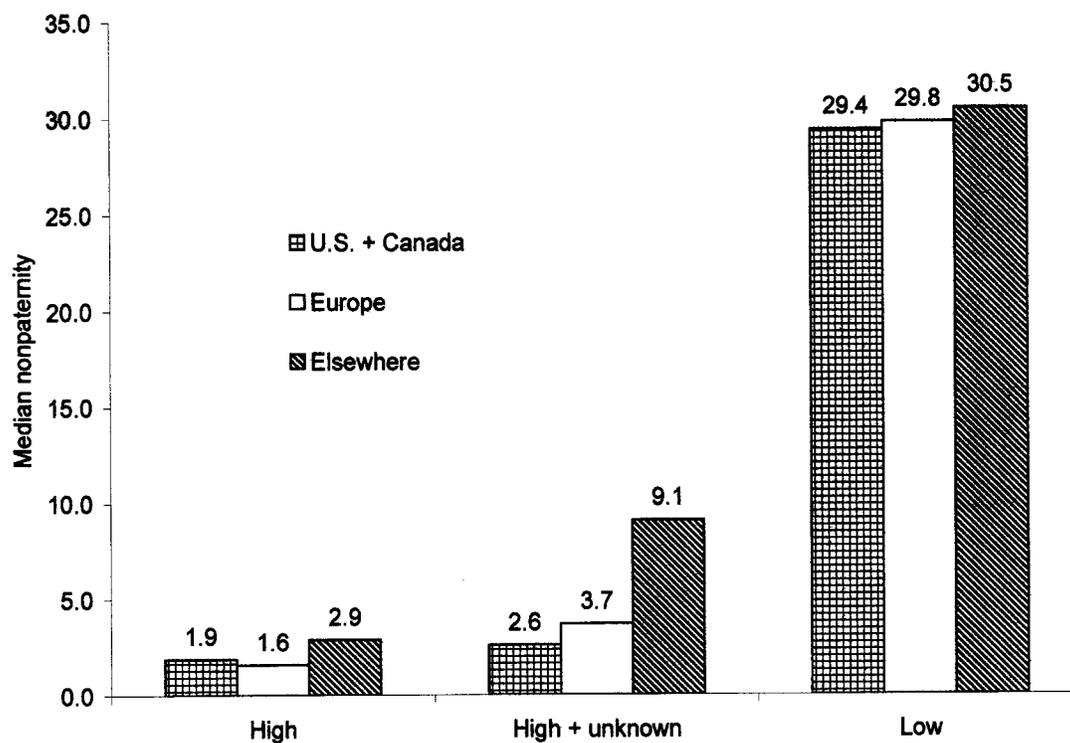


Figure 1. Median nonpaternity rates by paternity confidence and geographic location.

tion? Since most if not all samples are biased toward men with either high or low paternity confidence, this question cannot yet be answered. Presumably the true level of nonpaternity is a weighted average of men from these two groups, raising the question of how many men have low versus high paternity confidence. For example, in order for the population nonpaternity rate to be 10%, 75% of men in the population would have to have high paternity confidence (nonpaternity = 3.3%) and 25% low paternity confidence (nonpaternity = 29.8%). Anderson, Kaplan, and Lancaster (2005b) report that men living in Albuquerque, New Mexico, do not believe that they are the fathers of 1.46% of children attributed to them, implying a total nonpaternity rate for that sample of 3.7%. I know of no other study that has estimated the frequency of low and high paternity confidence within a particular sample, though this clearly has important implications for child well-being and family dynamics. Further cross-cultural investigation of the relationship between paternity and paternity confidence is warranted.

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