Sex Differences in Human Mate Preferences Vary Across Sex Ratios

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Abstract

A wide range of literature connects sex ratio and mating behaviours in non-human animals. However, research examining sex ratio and human mating is limited in scope. Prior work has examined the relationship between sex ratio and desire for short-term, uncommitted mating as well as outcomes such as marriage and divorce rates. Less empirical attention has been directed towards the relationship between sex ratio and mate preferences, despite the importance of mate preferences in the human mating literature. To address this gap, we examined sex ratio's relationship to the variation in preferences for attractiveness, resources, kindness, intelligence, and health in a long-term mate across 45 countries (N = 14,487). We predicted that mate preferences would vary according to relative power of choice on the mating market, with increased power derived from having relatively few competitors and numerous potential mates. We found that each sex tended to report more demanding preferences for attractiveness and resources where the opposite sex was abundant, compared to where the opposite sex was scarce. This pattern dovetails with those found for mating strategies in humans and mate preferences across species, highlighting the importance of sex ratio for understanding variation in human mate preferences.

Key words: mate preferences, sex ratio, sex differences, cross-cultural, mating market

Sex Differences in Human Mate Preferences Vary Across Sex Ratios

The varied relationship between sex ratio and reproductive processes has been studied across species and mating behaviours (1,2). For example, shorebird mating systems tend to vary across sex ratios: females tend to have multiple mates in species with typically male-biased sex ratios, whereas males tend to have multiple mates in species with female-biased sex ratios (3). Additionally, fluctuations in sex ratio within a single species can also be associated with variance in mating behaviours. For instance, the male European bitterling, a freshwater fish, changes mating tactics from defending territory to direct competition as the number of same sex rivals increases (4); female honey locust beetles increase competitive mating effort as females become more abundant than males (5); and female guppies display stronger preferences for orange coloured males as males outnumber females (6).

Yet, despite the breadth of research on sex ratio and mating in non-human animals, research on sex ratio and human mating is surprisingly narrow. Within this literature, most work has examined sex ratio's relationship to "mating strategy" (7)—one's investment in long-term, committed mating, as opposed to short-term, uncommitted mating—and its consequences (e.g. for marriage rates (8)). Despite mate preferences being among the most important topics in the human mating literature (9), comparatively little empirical attention has been given to the relationship between sex ratio and mate preferences. Here, to address this gap in the literature, we examined the relationship between sex ratio and mate preferences in a large cross-cultural sample spanning 45 countries around the world, and find evidence that mate preferences vary systematically with the ratio of potential mates to potential competitors.

Human males and females face a key challenge of finding and attracting long-term mates that are both desirable and available. An imbalanced sex ratio, where the number of males and

159 the number females in a population are unequal, exacerbates this challenge by affecting the
160 supply and demand of mating opportunities (10, cf. 11). The more abundant sex has a reduced
161 probability of gaining access to potential partners, whereas the scarcer sex has access to a wider
162 array of potential partners. The consequences of sex ratio imbalance are made worse by the fact
163 that human mating systems tend to be marked by relative monogamy and mutual mate choice
164 (12,13). Therefore, power on the mating market—power to express and fulfil one's desires—lies
165 with the sex in demand: the scarcer sex. Throughout human evolutionary history, individuals
166 endowed with a mating psychology sensitive to these power differentials, able to upregulate the
167 expression of sex-typical desires when one's sex is scarce and downregulate these desires when
168 one's sex is numerous, would likely have had a competitive advantage over individuals with
169 desires that remained static in the face of shifting contexts.

170 The effects of this sex differential in market power in humans have primarily been
171 studied in the context of mating strategy attitudes and behaviours. Men, owing to their smaller
172 obligatory investment in offspring, can potentially derive greater direct fitness benefits from
173 acquiring multiple mates than can women (14). Consequently, across cultures, men on average
174 report greater willingness to engage in sex without commitment—a higher "sociosexuality"—
175 than women (15,16).

176 However, this average sex difference is qualified by the finding that nation-level indices
177 of sociosexuality are higher in countries where men are scarce, and therefore have more market
178 power (15). This replicates outside of industrialized cultures: for instance, one study found that
179 men's sociosexuality varied across communities within the indigenous Makushi as a function of
180 the sex ratio of those communities (17). Behaviourally, marriage rates increase and divorce rates
181 decrease when women are scarce (18–20).

The same market forces that shape sociosexuality should also have consequences for mate preferences. Mate preferences, in general, have received extensive empirical attention. A large body of literature has documented universal trends in long-term mate preferences, including the importance of kindness, intelligence, and health, and universal sex differences in preference for physical attractiveness, resources, and relative age (21,22). Importantly, these preferences do predict real mate choices (23–26 cf. 27). While these on-average patterns of mate preferences have been consistently documented across time and cultures, the effect sizes of sex differences in mate preferences do vary across cultures. Sex ratio may be a source of the cross-cultural variation in mate preferences, just as it is for mating strategy.

The limited existing literature examining sex ratio and human mate preferences is marked by inconsistencies. One large cross-cultural study found that both men and women placed greater importance on good financial prospects, refinement and neatness, and other qualities in countries where men were more numerous than women (28). This is unexpected from a market economic perspective, where the change in men's and women's preferences should be inversely related due to differing relative power on the mating market. Yet this cross-cultural study, while impressive in sample size, had important methodological limitations, including analysing exclusively aggregate country-level correlations and incorporating a measure of preferences that allowed only limited variation (29). Another study found that in Canadian cities where women were relatively scarce, they placed more emphasis on the physical attractiveness of potential mates in newspaper ads (30); however, this study did not examine men's preferences. Lastly, measurement of sex ratio is not consistent across prior studies examining the consequences of sex ratio in humans, limiting generalizations across findings. For instance, studies vary in how they define sex ratio, and whether operational sex ratio (only individuals able to reproduce) or

adult sex ratio (all individuals considered adults, including elderly) is the key variable. Therefore, studies vary in the age range for which sex ratio is estimated, with ranges including ages 15-49 (28); ages 18-45 (17); ages 20-50 (20); ages 16-39 (31); ages 15-64 (29). Addressing these limitations will be important for understanding how human mate preferences relate to the scarcity or abundance of potential mates in their environment and whether this relationship is consistent with prior psychological, anthropological, and biological literature.

In the present investigation, we examined the relationship between mate preferences and sex ratio in a large, 45-country sample. First, we asked both men and women about their preferences for five traits in an ideal long-term mate and examined how these preferences varied across countries as a function of sex ratio. We analysed the data using multi-level models to account for the nested nature of the data and to take advantage of the large sample size, rather than relying on aggregate correlations. Furthermore, in an attempt to correct for issues in prior work, we incorporated city-level sex ratio and multiple measures of sex ratio at the country-level. Additionally, we measured preferences both in an absolute form (the trait value indicated as ideal in a potential mate) and as a relative preference (ideal trait value relative to the trait distribution available in each country) to allow for clearer comparisons across samples.

Overall, both men and women were predicted to have greater absolute and relative preferences where they were the scarcer sex. Members of the more numerous sex were predicted to have the opposite pattern and express less demanding mate preferences.

Method

Participants

Data were collected in 2016, from n = 14,487 (7,961 female, 54.95%) participants in 45 countries. All participant data were collected in person because online samples tend to be less

representative of populations in developing countries (32). Each study site collected data from both university populations and community samples. However, due to a lack of records from about half of the sites, there is incomplete information about the percentage of each type of sample. From the sites that did keep records (n = 6,637), 47.14% (n = 3,129) came from community samples. Age of participants ranged from 18-91 years old (Mdn = 25, M = 28.79, SD = 10.64). Of the total sample, most participants reported being in ongoing, committed relationships (n = 9,236, 63.75%). Overall, participants tended to be from large cities, to be well-educated, and have average economic situations (detailed city and participant demographic information is in the supplementary material).

Surveys were translated if necessary and distributed to participants through a collaborative cross-cultural data collection project. For more details and a complete list of countries and sample sizes, see the supplementary material.

The data from this cross-cultural data collection process have been used in other papers published previously (22,33–35).

Measures

Mate Preferences and Participant Traits. Participants completed a 5-item questionnaire on ideal mate preferences for a long-term romantic partner. Participants rated their ideal romantic partner on five traits: kindness, intelligence, health, physical attractiveness, and good financial prospects. All items were rated on bipolar adjective scales ranging from 1 (very unintelligent; very unkind; very unhealthy; very physically unattractive; very poor financial prospects) to 7 (very intelligent; very kind; very healthy, very physically attractive; very good financial prospects). Using the same scales as for preferences, participants additionally rated

themselves on the same five traits: kindness, intelligence, health, physical attractiveness, and good financial prospects. We also asked participants about their sex (male/female).

Sex Ratio. We used a variety of measures of sex ratio from publicly available databases. As there is no literature standard measure of sex ratio in humans, we wanted to examine the relationship between mate preferences and a variety of measures of sex ratio. We used country-level sex ratio at birth (36), adult sex ratio (ages 18+) (37), sex ratio for ages 15-49 (37), sex ratio for ages 15-64 (37), and city-level overall sex ratio (38–42). For city-level sex ratio we cross-checked local sources of information about sex ratio when possible. We also confirmed that city-level sex ratio was correlated with country level-sex ratio measures (sex ratio at birth, $r = 0.16$; adult sex ratio, $r = 0.79$; sex ratio ages 15-49, $r = 0.33$; sex ratio ages 15-64, $r = 0.57$). To explore whether participant's mate preferences were influenced by the sex ratio of their own age group, we also examined the relationship between mate preferences and sex ratio of narrower age categories: sex ratio ages 15-24, sex ratio ages 25-49, and sex ratio 50+ (37) (see supplemental material). For every sex ratio measure, we attempted to collect the publicly available data that were closest to 2016, which was the year we collected preferences and traits from participants.

Control Variables. Each analysis was conducted twice; first without controls, and then with all control variables simultaneously. Control variables include latitude (43), world region (defined in (44)), country religion (45), GDP per capita (46), gender equality (a composite measure of gender equality from a principal component analysis of three measures of gender equality: the Global Gender Gap Index (47), the Gender Inequality Index (GII) (48), and the Gender Development Index (49)), income inequality (the Gini Index (50)), and socioeconomic development (socioeconomic development is defined (51) as the summed standardized scores for

country's gross national income (GNI) (52), infant survival rate (53), life expectancy (54), and the percentage of population that is urban (55)). For all controls, we attempted to collect the publicly available data that was closest to 2016, which was the year we collected preferences and traits from participants (see supplementary material for more details and justification of the control variables).

Analyses

We conducted all primary analyses using multilevel models. The general format of these models predicted preference variables as the outcome variable using the interaction of sex and sex ratio variables; participants were nested within countries or cities, as appropriate. The models included random effects for both slopes and intercepts. Multilevel models provide advantages over traditional approaches for analysing these kinds of cross-cultural data. For cross-cultural comparisons, these models take advantage of the nested nature of the data, yielding more statistical power relative to the traditional approach of calculating correlations based on aggregated nation-level data (29).

Additionally, for all analyses, we report the results from a model with all of the controls included simultaneously in the main text, and the results from a base model with no controls in the supplementary materials. We note the pattern of results of the models without controls in the main text.

Data for this project was collected in 2016, and the analysis plan was pre-registered in 2019, prior to the data analysis for this project. The idea for the current project came from observing the overall pattern of variation in sex differences in mate preferences across countries in a prior study using the same mate preference data (22). To mitigate our own biases, we pre-registered our analysis plan for the current project before examining sex ratio as a possible

source of variation. All data analysis was done in R. The pre-registered analysis plan, analysis script, and data can be found on the Open Science Framework: https://osf.io/fpsm6/?view_only=b251a765273140b08099b20c249d693c.

Relative Mate Preferences. Relative preferences are calculated from absolute trait preferences but incorporate the trait distribution (mean and standard deviation) of each sex in each country, like a *z*-score. The reason for including relative preferences is to account for the fact that the same absolute preferred trait value may be more or less demanding depending on the availability of that trait in the local population. Therefore, relative mate preferences were calculated using the following formula:

$$relative\ preference = \frac{preference - M_{opp.\ sex\ trait}}{SD_{opp.\ sex\ trait}}$$

Each participant has a relative preference value for each trait, which indicates how high or low their ideal preference is for each trait, relative to the average trait level found in the opposite sex in their country. In the pre-registration, relative mate preferences were originally referred to as standards. We changed the term later for clarity.

Results

Absolute Mate Preferences and Sex Ratio

Table 1 shows the results of multilevel models predicting absolute ideal mate preferences from sex and sex ratio, with control variables. The interaction between sex and sex ratio predicted absolute preference for physical attractiveness for every measure of sex ratio. Additionally, the interaction between sex and sex ratio at birth predicted most absolute mate preferences, with the exception of kindness. Effect sizes for all significant models are in the supplementary materials. Removing control variables did not change the pattern of results (see supplementary material).

The number of models fitted may give cause for concern about alpha inflation. However, the intention of our analyses was to reveal any overall patterns between sex ratio generally and each preference, rather than detect individual significant effects. For this reason, multiple comparison corrections may be overly conservative. Although not pre-registered, to remove any such concerns we report both unadjusted *p*-values and *p*-values adjusted for multiple comparisons using Holm-Bonferroni corrections. For the purposes of these corrections, we corrected the *p*-values associated with the interactions and we considered the test families to be all analyses using any one of the sex ratio measures (e.g. sex and sex ratio at birth predicting good financial prospects, physical attractiveness, intelligence, kindness, and health). In Table 1 we report which models remained significant after the correction. For adjusted p-values see the supplementary materials.

Table 1

The Interaction Between Sex and Sex Ratio Predicting Absolute and Relative Mate Preferences

Preference	Sex Ratio Measure	*b* (sex ratio x sex)	*SE*	*p*
Good Financial Prospects	Birth	-0.088 (-0.099)	0.025 (0.043)	.001**† (.027*)
	Adult	-0.040 (-0.092)	0.029 (0.043)	.174 (.037*)
	15-49	-0.061 (-0.114)	0.026 (0.037)	.025* (.004**†)
	15-64	-0.048 (-0.103)	0.028 (0.040)	.087 (.013*)
	City	-0.044 (-0.084)	0.027 (0.037)	.108 (.028*)
Physical Attractiveness	Birth	-0.095 (-0.082)	0.025 (0.040)	<.001***† (.049*)
	Adult	-0.084 (-0.118)	0.027 (0.038)	.004**† (.003**†)
	15-49	-0.115 (-0.131)	0.023 (0.033)	<.001***† (<.001***†)
	15-64	-0.108 (-0.122)	0.024 (0.035)	<.001***† (.001**†)
	City	-0.083 (-0.123)	0.026 (0.033)	.002**† (<.001***†)
Intelligence	Birth	-0.076 (-0.025)	0.023 (0.043)	.002**† (.568)
	Adult	-0.014 (-0.011)	0.026 (0.042)	.604 (.789)
	15-49	-0.031 (-0.033)	0.025 (0.038)	.212 (.383)
	15-64	-0.018 (-0.011)	0.025 (0.039)	.486 (.784)
	City	-0.004 (-0.006)	0.026 (0.039)	.885 (.870)
Kindness	Birth	-0.011 (-0.002)	0.024 (0.038)	.668 (.965)
	Adult	-0.013 (-0.021)	0.025 (0.037)	.598 (.578)
	15-49	-0.004 (-0.032)	0.024 (0.033)	.856 (.330)
	15-64	-0.016 (-0.036)	0.024 (0.034)	.497 (.295)
	City	-0.021 (-0.037)	0.023 (0.034)	.362 (.288)
Health	Birth	-0.085 (-0.081)	0.023 (0.039)	<.001***† (.044*)

Adult	-0.023 (-0.048)	0.027 (0.039)	.401 (.226)
15-49	-0.038 (-0.069)	0.025 (0.034)	.134 (.051)
15-64	-0.034 (-0.074)	0.025 (0.036)	.183 (.045*)
City	-0.021 (-0.056)	0.024 (0.036)	.391 (.123)

Note: * = p < .05; ** = p < .01; *** = p < .001. Results for relative mate preferences shown in parentheses. † = remained significant after Holm-Bonferroni correction.

Physical Attractiveness. In general, as men became more numerous, women, relative to men, tended to increase their preference for physical attractiveness, whereas men, relative to women, decreased their preference for physical attractiveness (Figure 1). The magnitude of these simple slopes varied depending on the specific measure of sex ratio used; men had significantly negative slopes for adult sex ratio and city sex ratio, whereas women had significantly positive slopes for sex ratio ages 15-49 and sex ratio ages 15-64. All other simple slopes were not significantly different from zero (all *p*s greater than .05), however the relative differences still moved in the predicted direction. Overall, regardless of the sex ratio measure, the sex difference in absolute preference for physical attractiveness narrowed as the number of men, relative to women, increased.

Absolute Mate Preferences and Sex Ratio at Birth. The interaction between sex ratio at birth and sex additionally predicted absolute preference for physical attractiveness, good financial prospects, intelligence, and health. Generally, as sex ratio at birth skewed toward female scarcity, women's preferences tended to increase while men's preferences decreased (see supplementary material for figure). Specifically, simple slopes did not significantly differ from zero for physical attractiveness and health, however the relative slopes were in the predicted direction. Additionally, while women's absolute preference for good financial prospects increased, $b = 0.09$, $SE = 0.04$, $p = .023$, men's slope did not significantly differ from zero. Lastly, men's absolute preference for intelligence significantly decreased as men became more numerous, $b = -0.14$, $SE = 0.03$, $p < .001$. Contrary to prediction, women's intelligence

preferences decreased as well, b = -0.07, SE = 0.03, p = .039, however to a lesser degree than did men's.

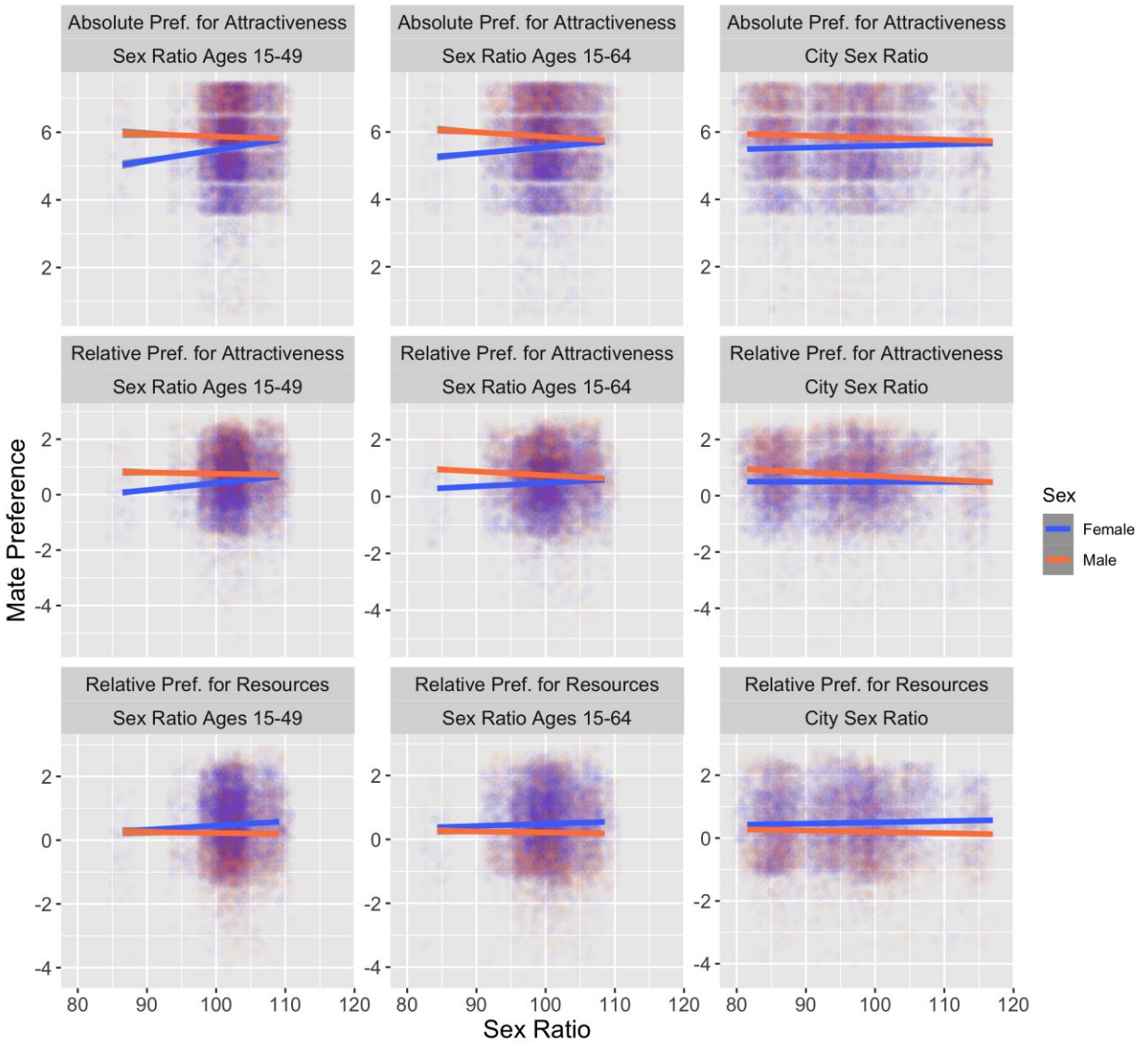

Figure 1. Participant mate preferences across sex ratios. Data are jittered to reduce overplotting. Regression lines, separated by sex, shown with shaded areas indicating 95% confidence intervals. The specific preference (absolute preference for physical attractiveness; relative preference for physical attractiveness; relative preference for good financial prospects) and

specific sex ratio (sex ratio ages 15-49; sex ratio ages 15-64; city sex ratio) can be identified in each plot label. Sex ratio is the number of males per 100 females.

Relative Mate Preferences and Sex Ratio

Table 1 shows the results of multilevel models predicting relative ideal mate preferences from sex and sex ratio, with control variables; results from models with relative preferences as the dependent variable are shown in parentheses. The interaction between sex and sex ratio predicted relative preference for good financial prospects and relative preference for physical attractiveness for every measure of sex ratio. Additionally, sex ratio at birth and sex ratio ages 15-64 predicted relative preference for health. However, because this result is not consistent across different measures of sex ratio, we do not focus on these analyses. Removing control variables did not change the overall pattern of results (see supplementary material).

Good Financial Prospects. In general, as men became more numerous, men, compared to women, decreased their relative preferences for good financial prospects, whereas women, compared to men, tended to increase their relative preferences for good financial prospects (Figure 1). All simple slopes were not significantly different from zero (all *p*s greater than .05), however the relative differences still moved in the predicted direction. Overall, the sex difference in relative preference for good financial prospects widened as sex ratio increased.

Physical Attractiveness. In general, as with absolute preference, as men became more numerous, men decreased their relative preference for physical attractiveness whereas women tended to increase their relative preference for physical attractiveness (Figure 1). The magnitude of these simple slopes varied depending on the specific measure of sex ratio used; men had significantly negative slopes for adult sex ratio and city sex ratio whereas women had significantly positive slopes for sex ratio ages 15-49 and sex ratio ages 15-64. All other simple

slopes were not significantly different from zero (all *p*s greater than .05), however the relative differences still moved in the predicted direction. Overall, regardless of the sex ratio measure, the sex difference in relative preference for physical attractiveness narrowed as the number of men, relative to women, increased.

Additional Analyses. Though not in the preregistration, in order to address concerns about non-independence between countries and cities, we further examined the effect of including controls for both country and city level proximity (56) and language (57). Additionally, we examined we examined the effect of nesting countries by language. Including these controls or changes in model structure did not change the pattern of results (see the supplementary material).

We included a covariation summary table in the supplementary material that includes the dependent variables and continuous control variables. Due to concerns about preferences not being independent (correlations between preferences range from r=0.22 to r = 0.39), we also conducted a principal components analysis, and used the principal components as dependent variables to test if the results had a similar pattern when preferences were no longer independent. Overall, the pattern of results remained consistent with the main analyses results (see supplementary material).

Discussion

The consequences of sex ratio skew have long been of interest to scientists of evolution and behaviour, and particularly of interest to those who study mating (18,58). Additionally, more recent work has examined the complex role of mate scarcity or abundance in patterns of sex differentiated reproductive behaviour, such as mate competition and parental care across species (59). Despite these important advances, empirical work connecting human mate preferences to

sex ratio remains scarce (for review, see (60)). Here, we attempted to address this literature gap with a large, cross-cultural investigation of human mate preferences. Overall, we found that sex differences in mate preferences vary across sex ratios. Where men are numerous, compared to where they are scarce, men tended to have lower absolute preferences for physical attractiveness whereas women tended to have higher preferences. This inverse relationship also held for relative preferences for both physical attractiveness and good financial prospects. In sum, each sex tended to report more demanding preferences for attractiveness and resources where they had more power of choice on the mating market, compared to where they had less mating market power.

These findings are important for several reasons. First, the pattern whereby the scarcer sex sets more demanding preferences falls parsimoniously in line with patterns found for mating strategies in humans (15,17), and for mating systems, mate competition, and mate preferences in non-humans (3,5,6). While this study is correlational in nature and cannot speak to causality, the pattern of results is what would be expected if preferences for attractiveness and resources were calibrated to mate availability, and thus plastic in response to mating market demand.

Second, as we show that men's and women's preferences vary across sex ratios inversely, the magnitude of average sex differences in preferences also varies. Much research has examined the universality of sex differences in human mate preferences (21,61). Less research has examined the variation in sex differences across cultures. The fact that sex ratio has the power to predict cross-cultural variation in mate preferences attains special importance as two previously reported sources of variation, pathogen prevalence and gender equality, have recently failed to replicate as predictors of cross-cultural variation in human mate preferences (22,44,62,63).

Third, that sex ratio more clearly predicts variation in relative preferences than in absolute preferences has implications for the measurement and analysis of mate preference variables. While absolute preferences reflect the trait values that people desire in potential mates, they do not as directly indicate how demanding that preference is within a particular environment. For instance, a strong preference for kindness (7 on a 7-point scale) may correspond to an extremely demanding preference in an environment where the average kindness is 4 on the same scale, or a somewhat demanding preference if the average kindness is 6 on the same scale. Given that scarcity on the mating market is hypothesized to afford power to express more stringent demands, measuring preferences in absolute terms might miss out on a critical dimension of variation relevant to sex ratio. Relative preferences, which incorporate information about the distribution of local trait values, may provide a more relevant measure of preferences in this context by virtue of providing a more direct measure of how demanding a given preference value is given participants' local contexts.

Despite these important findings, the study does have some limitations and leaves open some important questions. First, the relationship between sex ratio and mate preferences was not as robust for some mate preference dimensions: kindness, health, and intelligence. One possibility for why the same pattern did not emerge for these preferences is because they are so highly desired, and therefore more invariant. Indeed, the mean preference for kindness across all countries was, on a 7-point scale, $M = 6.23$, 95% CI [6.21, 6.26], $Mdn = 6$, for women, and $M = 6.12$, 95% CI [6.10, 6.15], $Mdn = 6$, for men. These universal near-ceiling effects leave limited room for variation. Furthermore, kindness, health, and intelligence are also qualities considered very important for both men and women, and therefore these preferences may be less likely to shift downward, even when market power is low (21,64). Future research could examine the

relationship between sex ratio and a wider range of mate preferences—crucially, including those that exhibit more variation—to determine the extent of the relationship between mate preferences and sex ratio.

Second, our finding that mate preferences vary according to current sex ratio at birth could be considered somewhat surprising. Theoretically, sex ratio at birth, the number of males born for every 100 females born, does not appear to typify the conceptual variable of interest: the number of mates available to members of each sex. However, sex ratio at birth is moderately correlated with the other measures of sex ratio ($r = 0.35$, adult sex ratio; $r = 0.39$, sex ratio 15-49; $r = 0.38$, sex ratio 15-65; $r = 0.16$, city sex ratio), so it may be capturing sex ratio variation similar to adult sex ratio measures. Additionally, sex ratio at birth is an important variable to consider because it may be the origin of some skewed adult sex ratios, particularly in countries with an abundance of men. In particular, sex ratio at birth may reflect aspects of gender relations. Though skewed sex ratios can occur because of migration, violence, and unbalanced death rates, sex ratio can also vary due to cultural practices such as sex selective abortions based on preferences for sons (65). Some prior work has hypothesized that in places where women are scarce, women may have less structural power overall, and may be unable to fulfil their mate preferences even when they hold mating market power (18). Although we did not find evidence consistent with this hypothesis—women's preferences tended to increase (not decrease) as they became scarcer—future work should continue to explore the source of sex ratio at birth's predictive power, including its potential relationship to gender equality.

Relatedly, our data do not speak to how the relationship between sex ratio and mate preferences emerges. One possibility is that the effects of sex ratio reflect evoked culture, and mating psychology reacts facultatively to local sex ratio to calibrate mate preferences.

Alternatively, this relationship could reflect transmitted culture if, for example, people with less strict preferences tend to experience greater mating success when their own sex is abundant, and others mimic their preferences via prestige-based learning (66). These possibilities are each equally consistent with the data we have here. Future research should explore further the particular ontogenetic mechanisms responsible for cross-cultural variation in preferences.

Furthermore, sex ratio measurement is made complicated by the fact that previous research has varied in the way sex ratio is defined. In particular, prior studies vary with respect to the age ranges used to estimate sex ratio, and whether operational sex ratio (only individuals able to reproduce) or adult sex ratio (all individuals considered adults, including elderly), is the key measure of sex ratio. Some of the inconsistent results in the prior literature may be due to researchers' use of only a single measure of sex ratio, which at times may fail to accurately capture the conceptual variable of interest: the availability of potential mates. Here we attempted to address this limitation by operationalizing country-level sex ratio measures in a variety of ways, and including city-level sex ratio and sex ratio at birth. By taking a broad approach to measuring sex ratio, we showed that results tended to remain robust across measures, though there were exceptions. However, a limitation of this broad approach is that it remains unclear what precisely is the best way to operationalize sex ratio for human mating research—a question future research must explore.

Part of the lack of clarity about how to operationalize sex ratio comes from the lack of clarity about how humans actually track mate availability. Country-level measures, or even city-level measures of sex ratio, may not accurately represent the sex ratios experienced and tracked by individual participants. More precise sex ratio measurements may produce different results than those found here.

499 Overall, the consequences of sex ratio have been well studied across mating behaviour in
500 the non-human literature, from intrasexual competition, to preferences, to mating system (3,5,6).
501 The consequences of sex ratio have also been examined in the human literature in areas spanning
502 from violence, to financial behaviour, to mating strategy (15,67,68). However, the question of
503 how sex ratio relates to human mate preferences has received limited attention and prior findings
504 have lacked clarity. Here we provided evidence that sex ratio is related to mate preferences
505 across cultures, such that where each sex is scarce, that sex tends to have higher preference
506 demands for attractiveness and resources. These findings further elucidate the nature of human
507 mating psychology, in particular its universal structure and systematic variation.
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