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Sexual Dimorphism in Waist-to-Hip Ratio and Divorce Frequency in Human Populations

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The current study tests a series of evolutionary predictions about the changing opportunities for human male mate choice and female Waist-to-Hip Ratio (WHR) across populations. We predicted that the divorce frequency (that we used as a reflection of the frequency of male mate choice) would be positively correlated with sexual dimorphism in WHRs across human populations. With published data, we built 2 samples, 1 at the international level and the other at the national level. The results showed that sexual dimorphism in WHR is positively correlated with the divorce-to-married ratio in 68 countries worldwide, as well as in the 32 Mexican states. Taken together, our results suggest that the opportunity for human male mate choice, based on female WHR, varies among human populations. We discuss the possibility of connecting this variation to human diversity in divorce practices. We conclude that human male mate choice is a circumstantially conditioned selective process responsible for such dimorphism and suggest that cultural and social aspects are potentially powerful in examining the factors capable of strengthening or weakening the selective process.

Keywords: divorce, waist-to-hip ratio, male mate choice

Mate choice is a selective ". . . process that occurs whenever the effects of traits expressed in one sex leads to nonrandom allocation of reproductive investment with members of the opposite sex" (Edward, 2015, p. 301). Research on mate choice has broadened its original focus from female mate choice to include male mate choice (Clutton-Brock, 2007). In this context, the current theory predicts that male mate choice will occur if the following sequence of circumstances is fulfilled: (a) the number of females available exceeds the ability of males to mate with them; (b) there is variation in female quality (i.e., in terms of fertility or parental ability, depending on age, size, and other factors); and (c) the benefit of choosing between females is greater than the cost of assessing them (Edward & Chapman, 2011; Johnstone, Reynolds, & Deutsch, 1996).

Several interdependent variables affect the relationship between female availability and ability of males to mate, changing the strength and consequences of the selective process (Andersson, 1994). The following paragraphs contain a brief description of variables and their effect on the evolution of mate choice in males.

1. A mating system describes the circumstances in which reproduction occurs within individual species (Darwin, 1871; Orians, 1969). Although mating systems have been related to the strength and con-

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sequences of sexual selection since the beginnings of evolutionary theory (Andersson, 1994; Darwin, 1871), there is still no universal agreement on its classification (Andersson, 1994). In some cases, the length and strength of the pair bond has been a useful criterion (Andersson, 1994). It can be expressed in terms of the number of mates per male or female in a given period, and is expected to reflect sex differences in strength and kind of sexual competition (Andersson, 1994; Shuster, 2009). This line of thought was used by Kraaijeveld (2003) to study ornamentation in birds. His comparative analysis showed that frequency of mate choice positively correlated with mutual ornamentation. An interesting find was that he measured the frequency of mate choice in terms of "divorce" rates (i.e., serial social monogamy would intensify sexual selection and the subsequent evolution of traits).

2. Parental Investment (PI) encompasses several kinds of resources that parents give to their progeny (e.g., energy and time). PI increases the offspring's chance of survival, while decreasing the parents' ability to invest in other offspring (Trivers, 1972). The behavioral component of PI—parental care—correlates negatively with the capacity to mate, as it is time consuming. Sexual differences in PI affect the relative availability of individuals of each sex to mate. Therefore, if the male gives more PI than the female, male mate choice will be facilitated. Otherwise, it will be hindered.
3. The Operational Sex Ratio (OSR), originally defined as the ratio of sexually active males to sexually active females in a particular time and place (Emlen & Oring, 1977), is usually expressed as the ratio of sexually mature males to sexually receptive females (Shuster, 2009). A female-biased OSR may lead to the inability of a male to mate with all the sexually active females that he encounters. Thus, it may favor the evolution of female traits that reflect fertility and male mate choice (Clutton-Brock, 2007).
4. The Potential Reproductive Rate (PRR) is the potential production of offspring in a period (Clutton-Brock & Parker, 1992). Sex differences in PRR are associated with parental care. Particularly, high parental care by a male relative to that by a female results in a reduced male PRR and, therefore, male mate choice is expected (Edward & Chapman, 2011).
5. Mating effort is the investment in traits that increase the attractiveness of a male to females or that increase his success in intrasexual competition (Edward & Chapman, 2011; Kokko & Monaghan, 2001). High investment in mating effort can increase the number of females that are available to a male for mating, but can trade off with the capacity of the male to mate with all such females (Edward & Chapman, 2011, p. 648). Hence, male mate choice could be favored.
6. The Adult Sex Ratio (ASR) is the proportion of males in an adult population (Székely, Weissing, & Komdeur, 2014). A female-biased ASR (i.e., a low proportion of males in an adult population) is expected to correlate with male mate choice, because a male will have more opportunities to mate than a female (Székely, Weissing, & Komdeur, 2014). These interrelated variables allow predicting kind, intensity, and consequences of competition that each sex will face during the mating process (Andersson, 1994).

Waist-to-Hip Ratio

Waist-to-Hip Ratio (WHR) is an anthropometric approach to body fat distribution. WHR increases with body mass (Cornelissen, Toveé, & Bateson, 2009; Molarius et al., 1999; Shimokata et al., 1989) and age (Molarius et al., 1999; Shimokata et al., 1989). In several human populations, adult body fat distribution varies with sex (Marti et al., 1991; Vague, 1956). In addition, WHR is a health indicator. The World Health Organization (WHO, 2011, p. 27) established that a WHR beyond 0.90 in males and 0.85 in females increases the risk of cardiovascular and other diseases. The WHO (2011, p. 14) also recommended the use of ethnicity as an appropriate factor to make local adjustments. Stuntedness during early development increases adult WHR (Martorell, Stein, & Schroeder, 2001; Schroeder, Martorell, & Flores, 1999). Furthermore, WHR correlates negatively with

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female fertility (Molarius et al., 1999; Singh & Randall, 2007). In women, parity contributes to changes in body composition and body shape (WHO, 2011, p. 8). Menopause is another factor associated with increased total and central adiposity (Toth, Tchernof, Sites, & Poehlman, 2000).

Female Waist-to-Hip Ratio and Male Mate Choice

Human sex differences in WHR have been proposed to evolve through male mate choice (Singh, 1993a). Specifically, a male will prefer to mate with a female whose WHR is within the range of health, fertility, and youth (Singh, 1993a). Singh (1993a) developed a test that is composed by a series of 12 drawings of the female body. Each figure represents the intersection between one of three categories of the Body Mass Index (BMI) and one of four values of the WHR. With this test, he and other authors showed that males worldwide have a strong preference for the drawing representing a woman with a normal BMI and the lowest WHR, that is, 0.7 (Furnham, Dias, & McClelland, 1998; Furnham, Tan, & McManus, 1997; Henss, 1995; Singh, 1993a, 1993b, 1994a, 1994b; Singh & Luis, 1995; Singh & Young, 1995).

Contextual Influences on Male Preferences for the WHR

Delving into cultural issues, Yu and Shepard (1998) showed 6 of the 12 drawings by Singh to men from three Matsigenka villages in Peruvian Amazonia, whose contact with Western cultures vary. Their study revealed contrasting judgments about attractiveness, healthiness, and preferred spouse. The most culturally isolated inhabitants of Yomybato preferred a higher BMI without much regard for WHR; men in Shipietari favored a higher BMI and a lower WHR; and an ethnically mixed population of Alto Madre behaved as did Singh's first subjects. The authors argued that, in traditional societies, men have access to direct information about mate quality, and thus, physical signals are unnecessary to obtain indirect information. The preference for overweight women among the Matsigenka remained an isolated fact until Wetsman and Marlowe (1999) found a similar predilection among Hadza hunter-gatherer men in Tanzania: having been asked to evaluate attractiveness, healthiness, and suitable spouse using the female silhouettes, they expressed their preference for females with a higher BMI. Considering that the Hadza live under constant threat of food scarcity, the authors concluded that ecological conditions led them to rank BMI, not WHR, number one. Another interesting study was carried out by Sugiyama (2004) among the Shiwiar, a forager-horticulturist population from Amazonian Ecuador. The author found that men in this ethnic group preferred a lower-than-local-average female WHR, which led him to conclude that, rather than being anchored to absolute values, their proclivity was context sensitive.

Current Research

Researchers who focus on the male preference for female WHR seem to agree that, in all human populations, male mate choice is an ongoing process. Singh (1993a) maintained that males universally consider a lower female WHR more appealing than a higher female WHR, and Yu and Shepard (1998) said that traditional customs have an impact on the evaluation of attractiveness. In addition, Wetsman and Marlowe (1999) argued that ecological conditions shape psychological mechanisms that lead males to prefer certain female traits, whereas Sugiyama (2004) argued for adjusting the range of preferred WHRs to the locally available WHR range. Nevertheless, the conditions required for mate choice to occur are constantly changing in space and time. These changes are expected to reflect a variation in the strength of the selective processes. For instance, in Poland, the historical trend that childless males were shorter than males with at least one child was abruptly halted during the Second World War, because gender bias at recruitment changed the sex ratio during that period, weakening the strength of female mate choice of taller males (Pawlowski, Dunbar, & Lipowicz, 2000). Consequently, the overall expectation of this study was that interpopulation differences in variables theoretically linked to male mate choice (i.e., mating systems, OSR, paternal care, PRR, mating effort, and ASR) would be concomitant with variations in the traits of the females that are under selection.

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The above-described medical research shows that the human female WHR indicates health status, fertility potential, and age group. In other words, it can be considered an honest signal of the quality of a female mate. In addition, evolutionary research has found, at least in some human populations, a male preference for certain low WHR values, a finding that suggests that male mate choice is the selective process responsible for the human sexual dimorphism of body shape (i.e., the straight shape of men and the hourglass shape of women) found in several human groups (Singh, 1993a). Therefore, specifically, among the expectations of our research was that sexual dimorphism in WHR would vary across human groups, according to the variables that affect the strength of male mate choice.

Inspired by Kraaijeveld's (2003) study, we used the divorced to married ratio as an indicator of the mate choice frequency. Divorce frequency varies across human groups in accordance with several cultural factors (Hiller & Recoules, 2013). For instance, in the United States, Hispanics and African Americans remarry at lower rates than do White Americans (Coleman, Ganong, & Fine, 2000). Thus, we can expect the same variations in divorce frequencies across a wide range of human groups. In addition, divorce has a different effect on each sex. Chamie and Nsuly (1981) showed that divorced males were more likely to remarry than divorced females in 47 countries. These results are similar to those reported by Coleman, Ganong, and Fine (2000), which found that, in the United States, remarriage after divorce occurs at higher rates in males than in females. These findings suggest that the divorce frequency could reflect the frequency of male mate choice.

We predicted that the divorce frequency would positively correlate with the sexual dimorphism of WHRs in human groups. Such a correlation, however, would indicate sexual selection, not male mate choice. Therefore, we further predicted that the divorce frequency would negatively correlate with female WHR, and that it would not correlate with male WHR. We used this approach with two samples, one at the international level, and the other at the national level. We extended the approach of the national sample to test a series of predictions of ASR and OSR. Because female biased OSR may favor male mate choice (Clutton-Brock, 2007), and because the same is true for ASR (Liker, Freckleton, & Székely, 2014), we predicted that OSR and ASR would have a negative correlations with the sexual dimorphism of WHR.

Because variables that affect the intensity of male mate choice are interrelated, they are expected to be somehow correlated with one another. Research has shown that "divorce" rates in birds are more than twice as high in species with female-biased ASR as in male-biased species (Liker, Freckleton, & Székely, 2014). As such, in the current study, we surmised that divorce frequency would be negatively correlated with both ASR and OSR.

Study 1: The International Sample

Method

We performed a structured literature search for published data on WHR for 60% of the 241 countries enlisted in macro geographical regions, geographical subregions, and selected economic and other groupings by the United Nations (United Nations, 2014a). We distributed the search across geographical subregions, searching within a subregion until data from at least two countries were found. Using the Google Scholar search engine, we used the terms "waist to hip ratio" "<country name>" health—children—adolescents—exercise—attractiveness. We reduced the search to publications with dates from January 1, 1990 to October 21, 2016. Studies were selected if they reported separately for males and females the mean WHR, *SD* (studies with only confidence intervals were found, the *SD* was calculated) and the sample size of adults without an illness diagnosis. We excluded studies not available in English and non-full text articles. When more than one entry was found for a country, we (a) gave priority to national health surveys and other official reports over case studies, (b) selected articles with the larger sample size, (c) chose studies reporting several countries over those presenting results from a single population, (d) eliminated the oldest study, and (e) discarded entries presenting only elderly subjects.

We descriptively analyzed the sample by means of (a) the range of male and female

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WHRs of sampled countries and (b) the weighted means and *SD*s for male and female WHRs at the country level.

To evaluate the differences between male and female WHR in each human group, we used a series of statistical tests. We tested each sample (male and female WHR in each group) for normality with a Kolmogorov–Smirnov test. If results confirmed normality of both samples of a group, the assumption of equal variance (homoscedasticity) was examined using a Levene's test. If the samples proved to have similar variances, we used an independent sample *t* test; otherwise, we used a Welch's approximate *t* test. If normality of at least one of the two samples was not confirmed, we carried out a Kolmogorov–Smirnov test for two independent samples, because this test does not assume normality. We analyzed the effect size of sexual differences in mean WHR at the country level, using the software of the Erasmus Research Institute of Management (Van Rhee, et al., 2015).

We measured sexual dimorphism in WHR by dividing male WHR by female WHR (WHR_{male}/WHR_{female}). This is a common measure of sexual differences for continuous traits (Andersson, 1994, p. 86).

We obtained divorced-to-married ratios (DMRs) for each country from the World Marriage Data, 2012 database (United Nations, 2013). This database includes subjects from 15 years old. We calculated the DMR as the number of divorced females and males by the number of married females and males. Calculations were made with data from the year closest to that of when the WHR sample data were collected or the publication date.

We used a Pearson product–moment correlation test to analyze the relationships between the DMR and: (a) sexual dimorphism in WHR (WHR_{male}/WHR_{female}), (b) female WHR, and (c) male WHR.

Results

We found data on female and male WHR from 68 of the 145 countries included in the search (see Table 1). Some subregions of the UN list remained underrepresented. Although we searched for all countries of Central Asia, Southern Africa, and Melanesia, we did not find any data for the first subregion and we only found data from a single country for the last two (South Africa and Papua New Guinea, respectively).

The overall WHR ranged between 0.65 and 1.01. Males had a higher WHR than females ($M_{w\text{male WHR}} = 0.903$, $SD_{\text{wmale}} = 0.03$, $N_{\text{male}} = 82{,}946$; $M_{w\text{female WHR}} = 0.831$, $SD_{\text{wfemale}} = 0.04$, $N_{\text{female}} = 93{,}905$). Only females from Jordan, Senegal, and Angola had larger WHR than males, and females from Argentina, Guatemala, Islamic Republic of Iran, Pakistan, and Egypt had the same WHR as males (see Table 1).

The combined effect size was large (Hedges's $g = 1.14$, $ES = 0.11$, confidence interval [CI] Lower Limit = 0.93, CI Upper Limit = 1.35, PI Lower Limit = −0.46, PI Upper Limit = 2.74, $z = 10.85$, $p < .001$, $N_{\text{subjects}} = 176{,}851$, $N_{\text{countries}} = 68$). However, the effect sizes at the country level varied considerably (see Table 1). In fact, we found high heterogeneity ($I^2 = 99.68\%$). The effect sizes of the samples from South Africa and Denmark were even beyond the upper limit of the prediction interval. In almost all countries, the differences between males and females in WHR were statistically significant. The correspondent effect sizes were medium to large, excluding those of Jordan and Pakistan. There were no statistically significant differences between the means of male and female WHR in Senegal, Angola, Argentina, Egypt, Guatemala, the Islamic Republic of Iran, United Republic of Tanzania, Bangladesh, or the Cook Islands. Additionally, the effect sizes of these country-samples were small, except for the Cook Islands.

The DMR for 68 countries positively correlated with sexual dimorphism WHR_{male}/WHR_{female} ($r = .433$, $p < .001$, $N = 68$; see Figure 1). The DMR correlated negatively with female WHR ($r = -.476$, $p < .001$, $N = 68$), but had no correlation with male WHR ($r = -.112$, $p = .364$, $N = 68$). The DMR for 41 countries where large effect size of sexual differences in mean WHR was found positively correlated with sexual dimorphism in WHR ($r = .357$, $p < .001$, $N = 41$). The DMR negatively correlated with females WHR ($r = -.491$, $p < .001$, $N = 41$), but had not correlation with male WHR ($r = -.271$, $p = .086$, $N = 41$).

Table 1
Summary of Data and Analyses: International Sample

			WHR													Divorce	
			Males			Females			Effect size				Sex differences				
CC	Year	Age	M	SD	N	M	SD	N	g	CILL	CIUL	Mag	$WHR_{male}-WHR_{female}$	t	WHR_{male}/WHR_{female}	Year	DMR
SEN	2009	22–53	.85	.06	31	.88	.1	50	−.34	−.8	.11	S	−.03	$t_W = -1.51$ NS	.97	2010	.04
JOR	2008	≥25	.82	.07	394	.84	.07	727	−.29	−.41	−.16	S	−.02	$t_S = -4.57^*$	.98	2004	.01
AGO	2009	44.5 ± 10.6	.86	.09	294	.87	.08	321	−.12	−.28	.04	S	−.01	$t_W = -1.46$ NS	.99	1970	.01
EGY	1996	44.3 ± .6	.9	0	191	.9	.01	136	0	−.22	.22	S	0	$t_W = 0$ NS	1	1996	.01
ARG	2005	18–86	.9	.2	184	.9	.1	294	0	−.18	.18	S	0	$t_W = 0$NS	1	2001	.12
GTM	1988	18–25	.9	.04	319	.9	.06	547	0	−.14	.14	S	0	$t_W = 0$ NS	1	1994	.05
PAK	1998	≥25	.89	.08	679	.89	.08	829	0	−.1	.1	S	0	$t_S = 0^*$	1	1998	0
IRN	2002	≥19	.9	.09	6,381	.9	.1	6,381	0	−.03	.03	S	0	$t_W = 0$ NS	1	2006	.01
BGD	1997	30–64	.9	.08	499	.85	.9	205	.1	−.06	.26	S	.05	$t_W = 1.23$ NS	1.06	2001	.01
TZA	2002	44–66	.89	.05	115	.88	.07	94	.17	−.11	.44	S	.01	$t_W = 1.20$ NS	1.01	2002	.03
CHL	1998	≥20	.89	.01	618	.82	.01	866	.24	.14	.34	M	.07	$t_S = 132.93^*$	1.09	2002	.01
KEN	2010	18–90	.89	.01	1,049	.85	0	1,012	.3	.22	.39	M	.04	$t_W = 127.25^*$	1.05	2008	.02
KOR	2009	21–81	.92	.06	3,777	.9	.07	5,627	.3	.26	.34	M	.02	$t_W = 14.37^*$	1.02	2005	.05
TON	1998	>15	.89	.07	271	.83	.06	337	.34	.18	.5	M	.06	$t_W = 11.38^*$	1.07	1996	.03
NGA	2016	29–54	.91	.1	127	.87	.1	225	.4	.18	.62	M	.04	$t_S = 3.60^*$	1.05	2008	.18
WSM	2002	35–74	.94	.1	246	.87	.1	238	.45	.27	.63	M	.07	$t_S = 7.70^*$	1.08	2001	.04
PSE	1999	18–64	.9	.1	1,725	.85	.1	1,653	.5	.43	.57	M	.05	$t_S = 14.53^*$	1.06	2000	.02
VNM	2011	24–87	.89	.06	5,602	.86	.06	10,680	.5	.47	.53	M	.03	$t_S = 30.31^*$	1.03	2009	.02
IND	2003	≥20	.9	.07	4,961	.86	.08	5,507	.53	.49	.57	M	.04	$t_W = 27.09^*$	1.05	2001	.01
POL	2012	18	.86	.08	84	.82	.07	150	.54	.27	.81	M	.04	$t_S = 3.98^*$	1.05	2002	.06
JAM	1995	>25	.84	.07	524	.8	.07	733	.57	.46	.69	M	.04	$t_S = 9.99^*$	1.05	1991	.04
MAR	2008	>40	.93	.05	583	.89	.07	1,045	.63	.53	.73	M	.04	$t_W = 12.71^*$	1.04	2004	.04
CHN	1987	35–74	.87	.06	530	.82	.07	680	.76	.64	.88	M	.05	$t_W = 13.11^*$	1.06	1990	.01
CMR	1993	>25	.86	.06	612	.81	.07	749	.76	.65	.87	M	.05	$t_W = 13.97^*$	1.06	1998	.04
LCA	1993	>25	.87	.06	491	.82	.07	598	.76	.64	.88	M	.05	$t_W = 12.50^*$	1.06	1991	.04
COK	2002	35–74	.93	1.01	46	.87	.01	70	.77	.38	1.16	M	.06	$t_W = .50$ NS	1.07	1996	.05
REU	1999	30–30	.9	0	569	.84	0	745	.77	.66	.89	M	.06	$t_S = 359.23^*$	1.07	1999	.1
MYS	1992	>18	.86	.1	539	.78	.1	1,044	.8	.69	.91	L	.08	$t_S = 15.08^*$	1.1	1991	.02
DZA	1996	42.2 ± .8	.9	.01	82	.83	.01	48	.83	.47	1.21	L	.07	$t_S = 38.52^*$	1.08	2002	.02
BRB	1993	>25	.88	.07	330	.82	.07	483	.86	.71	1	L	.06	$t_S = 12^*$	1.07	1990	.14
BES	1999	>18	.9	.07	1,019	.83	.08	1,006	.93	.84	1.02	L	.07	$t_W = 20.96^*$	1.08	2001	.18
MEX	1994	≥20	.91	.05	2,426	.84	.07	5,939	1.08	1.03	1.13	L	.07	$t_W = 44.81^*$	1.08	1990	.02
BGR	1996	49.64 ± .7	.9	.01	145	.77	.01	143	1.08	.84	1.33	L	.13	$t_S = 110.31^*$	1.17	1990	.06
IDN	2007	40–60	.98	.06	44	.93	.04	127	1.08	.73	1.45	L	.05	$t_S = 6.22^*$	1.05	2010	.03
GIN	2003	>35	.93	.04	730	.9	0	807	1.09	.98	1.2	L	.03	$t_S = 21.31^*$	1.03	2005	.01
ZWE	1995	>25	.87	.05	259	.81	.06	203	1.1	.9	1.3	L	.06	$t_W = 11.72^*$	1.07	1992	.08
KWT	1999	17–60	.88	.06	72	.8	.08	105	1.1	.78	1.42	L	.08	$t_S = 7.21^*$	1.1	1995	.02
JPN	1996	20–58	.86	.06	4,229	.79	.07	2,433	1.13	1.08	1.19	L	.07	$t_W = 44.55^*$	1.09	1995	.05
GRC	1996	48.1 ± .7	.94	0	225	.83	.01	193	1.16	.95	1.37	L	.11	$t_W = 165.03^*$	1.13	1991	.03
SGP	2012	21–74	.88	.06	415	.8	.07	1,476	1.18	1.06	1.29	L	.08	$t_W = 21.19^*$	1.1	2010	.06
LKA	2005	30–65	.93	.07	2,692	.83	.09	3,355	1.22	1.17	1.28	L	.1	$t_W = 47.30^*$	1.12	2001	0
THA	2003	20–40	.83	.06	16	.77	.03	16	1.23	.49	2.04	L	.06	$t_W = 3.58^*$	1.08	2000	.01
BRA	2003	20–83	.94	.07	35	.84	.08	57	1.3	.85	1.77	L	.1	$t_S = 6.10^*$	1.12	2000	.03
ITA	1987	35–74	.91	.06	1,267	.82	.07	1,304	1.38	1.29	1.47	L	.09	$t_W = 34.96^*$	1.11	1991	.03
PNG	1991	>20	.89	.05	436	.82	.05	584	1.4	1.26	1.54	L	.07	$t_S = 22.12^*$	1.09	2006	.02
MUS	1992	>20	.92	.05	1,737	.84	.06	1,960	1.44	1.37	1.51	L	.08	$t_W = 43.72^*$	1.1	1990	.01
CZE	1987	35–74	.94	.06	1,035	.84	.07	1,068	1.53	1.43	1.63	L	.1	$t_W = 35.13^*$	1.12	1991	.11
NLD	1993	20–59	.9	.07	2,183	.79	.07	2,698	1.57	1.51	1.64	L	.11	$t_S = 54.59^*$	1.14	1995	.11
CAN	1986	18–74	.9	0	4,951	.78	0	4,962	1.7	1.66	1.75	L	.12	$t_{W>} 1000^*$	1.15	1986	.06
ETH	2012	>15	1.01	.12	308	.86	.05	426	1.73	1.56	1.9	L	.15	$t_W = 23.17^*$	1.17	2011	.05
CRI	1988	41 ± 13	.89	.05	103	.81	.04	88	1.74	1.42	2.09	L	.08	$t_W = 12.07^*$	1.1	1984	.03
SRB	1987	35–74	.93	.06	599	.82	.06	598	1.83	1.7	1.97	L	.11	$t_S = 31.71^*$	1.13	2002	.07
EST	2014	22–65	.91	.06	285	.75	.1	428	1.85	1.68	2.03	L	.16	$t_W = 24.26^*$	1.21	2000	.2
GBR	1987	35–74	.94	.08	568	.8	.07	634	1.87	1.73	2.01	L	.14	$t_W = 32.36^*$	1.18	1991	.11
DEU	1987	35–74	.93	.06	1,768	.81	.06	1,881	2	1.92	2.08	L	.12	$t_S = 60.38^*$	1.15	1990	.09s
USA	2003	18–44	.87	.05	773	.76	.06	576	2.02	1.89	2.15	L	.11	$t_W = 36.67^*$	1.14	2000	.18
NZL	2002	35–74	.93	0	863	.81	0	882	2.03	1.92	2.15	L	.12	$t_S = 1253.12^*$	1.15	2001	.09
NOR	1995	43±	.89	.05	11,925	.78	.06	7,791	2.03	2	2.07	L	.11	$t_W = 139.39^*$	1.14	1996	.15

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Table 1 (*continued*)

			WHR													Divorce	
			Males			Females			Effect size				Sex differences				
CC	Year	Age	*M*	*SD*	*N*	*M*	*SD*	*N*	*g*	CILL	CIUL	Mag	$WHR_{male}-WHR_{female}$	*t*	WHR_{male}/WHR_{female}	Year	DMR
AUS	1987	35–74	.92	.06	1,308	.78	.07	1,313	2.15	2.05	2.24	L	.14	$t_W = 54.96^*$	1.18	1986	.08
HUN	2014	18–30	.79	.04	76	.71	.03	122	2.33	1.97	2.71	L	.08	$t_W = 16.12^*$	1.11	2010	.24
TUR	1987	35–74	.96	.04	78	.84	.06	79	2.34	1.94	2.76	L	.12	$t_W = 14.73^*$	1.14	1985	.01
SWE	1987	35–74	.93	.05	1,220	.8	.06	1,232	2.35	2.25	2.46	L	.13	$t_W = 58.25^*$	1.16	1985	.17
LVA	2012	19–23	.83	.04	28	.73	.04	54	2.48	1.9	3.1	L	.1	$t_S = 10.74^*$	1.14	2011	.32
FIN	1987	35–74	.93	.06	4,752	.78	.06	5,170	2.5	2.45	2.55	L	.15	$t_S = 124.40^*$	1.19	1990	.15
CHE	1988	35–64	.92	.06	548	.78	.05	572	2.54	2.38	2.7	L	.14	$t_W = 42.49^*$	1.18	1995	.11
ESP	1987	35–74	.97	.05	1,325	.83	.06	779	2.6	2.48	2.71	L	.14	$t_W = 57.51^*$	1.17	1991	.01
DNK	1987	35–74	.99	.05	568	.82	.06	565	3.08	2.91	3.25	L	.17	$t_W = 51.82^*$	1.21	1985	.13
ZAF	2009	>18	.75	.04	82	.65	.02	205	3.66	3.28	4.07	L	.1	$t_W = 28.11^*$	1.15	2011	.06

Note. CC = Country code according to United Nations (2014b); WHR = waist-to-hip ratio; M_{male} = mean of male WHR; SD_{male} = *SD* for males; N_{male} = male sample size; $M_{♀}$ = mean of female WHR; SD_{female} = *SD* for females; N_{female} = female sample size; $M_{male}-M_{female}$ = difference between the means of males and females WHR; t_S = Student's *t*; t_W = Welch's *t*; NS = statistically nonsignificant; * = statistically significant; g = Hedges' g; CI LL and CI UL = 95% lower and upper confidence intervals of the Hedges' *g*; Mag = Magnitude of the effect size; $M_{♂}/M_{♀}$ = sexual dimorphism in WHR (male WHR relative to female WHR); and DMR = divorce to married ratio. References for WHR data: SEN = Senegal (Cohen et al., 2015); JOR = Jordan (Khader et al., 2008); AGO = Angola (Magalhães et al., 2014); EGY = Egypt (Karamanos et al., 2002); ARG = Argentina (Romaguera et al., 1998); GTM = Guatemala (Schroeder & Martorell, 1999); PAK = Pakistan (Shera et al., 2010); IRN = Islamic Republic of Iran (Sadeghi et al., 2004); BGD = Bangladesh (Abu Sayeed et al., 1997); TZA = United Republic of Tanzania (Njelekela et al., 2009); CHL = Chile (Miquel et al., 1998); KEN = Kenya (Joshi et al., 2014); KOR = Republic of Korea (Lee & Kim, 2014); TON = Tonga (Colagiuri et al., 2002); NGA = Nigeria (Adeoye et al., 2016); WSM = Samoa (Sundborn et al., 2008); PSE = State of Palestine (Abdeen et al., 2012); VNM = Viet Nam (Pham & Eggleston, 2016); IND = India (Snehalatha et al., 2003); POL = Poland (Klimek-Piotrowska et al., 2015); JAM = Jamaica (Cooper et al., 1997); MAR = Morocco (Randani et al., 2012); CHN = China (Molarius et al., 1999); CMR = Cameroon (Rotimi et al., 1995); LCA = Saint Lucia (Rotimi et al., 1995); COK = Cook Islands (Sundborn et al., 2008); REU = Réunion (Favier et al., 2005); MYS = Malaysia (Khor et al., 1999); DZA = Algeria (Karamanos et al., 2002); BRB = Barbados (Rotimi et al., 1995); BES = Bonaire, Sint and Saba (Grievink et al., 2004); MEX = Mexico (Berber et al., 2001); BGR = Bulgaria (Karamanos et al., 2002); IDN = Indonesia (Hardiman et al., 2016); GIN = Guinea (Baldé et al., 2007); ZWE = Zimbabwe (Mufunda et al., 2000); KWT = Kuwait (Akanji et al., 1999); JPN = Japan (Ishizaki et al., 2004); GRC = Greece (Karamanos et al., 2002); SGP = Singapore (Lam et al., 2015); LKA = Sri Lanka (Wijewardene et al., 2005); THA = Thailand (Rattarasarn et al., 2003); BRA = Brazil (Sampaio et al., 2007); ITA = Italy (Molarius et al., 1999); PNG = Papua New Guinea (Snijder et al., 2004); MUS = Mauritius (Snijder et al., 2004); CZE = Czech Republic (Molarius et al., 1999); NLD = Netherlands (Han et al., 1995); CAN = Canada (Dobbelsteyn et al., 2001); ETH = Ethiopia (Gudina et al., 2013); CRI = Costa Rica (Campos et al., 1991); SRB = Serbia (Molarius et al., 1999); EST = Estonia (Kaldmäe et al., 2014); GBR = United Kingdom of Great Britain and Northern Ireland (Molarius et al., 1999); DEU = Germany (Molarius et al., 1999); USA = United States of America (Hughes & Gallup, 2003); NZL = New Zealand (Sundborn et al., 2008); NOR = Norway (Pettersen, 2009); AUS = Australia (Molarius et al., 1999); HUN = Hungary (Uvacsek et al., 2014); TUR = Turkey (Onat et al., 2004); SWE = Sweden (Molarius et al., 1999); LVA = Latvia (Irena et al., 2012); FIN = Finland (Molarius et al., 1999); CHE = Switzerland (Costanza & Paccaud, 2004); ESP = Spain (Molarius et al., 1999); DNK = Denmark (Molarius et al., 1999); ZAF = South Africa (Matsha et al., 2013).

Study 2: The National Sample

Method

The data sources used for the above analysis were heterogeneous in many ways (i.e., the WHR data came from diverse sample sizes, age ranges, and physiological conditions, apart from the fact that subjects differed in their cultural and social backgrounds). In an attempt to improve the accuracy of our interpretation, the current study included data from a single database—the 2012 Mexican National Health and Nutrition Survey (ENSANUT, 2012; for methodological details on the survey, see Romero-Martínez et al., 2013).

We examined several variables for each respondent. These included place of residence at the state level, sex, age, marital status, waist circumference, hip circumference, height, cate-

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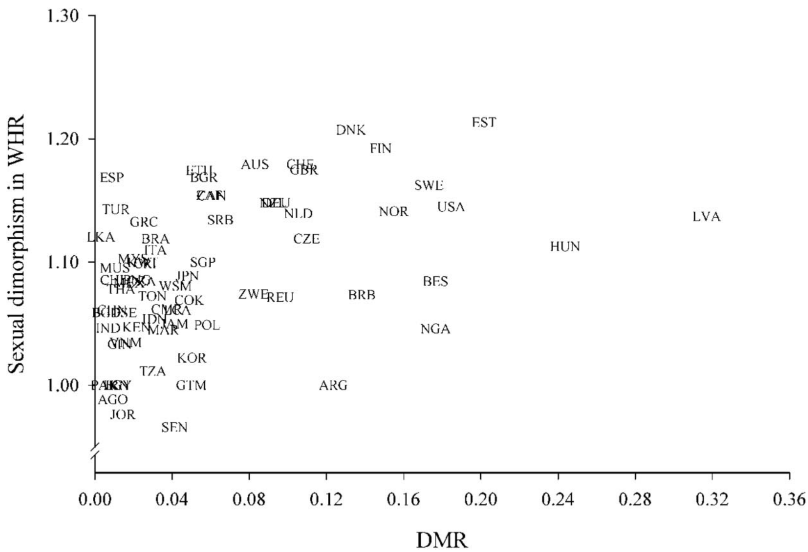

Figure 1. Positive correlation between divorced-to-married ratio (DMR) and sexual dimorphism in waist-to-hip ratio (WHR) at international level ($r = 0.433$, $p < 0.001$, $N = 68$). See the footnote of Table 1 for codes.

gory of BMI, number of childbirths, and physiological status (if a female was pregnant, breastfeeding, both, or none). Interestingly, not all survey questions were asked to all respondents. For instance, the minimum age of women who were asked about the number of childbirths was 20 years, but the question on marital status was posed to all individuals aged 12 and older. Further, another important issue is that the Mexican population shows at least two age-related differences from other populations, namely, legal adulthood starts at 18 years of age and the approximate age at menopause ranges from 48 to 50 years (Bassol-Mayagoitia, 2006).

As pointed out in the introduction, the effects of some variables on WHR are well-known. We could not guarantee that covariables of WHR (i.e., body mass, age, early developmental stuntedness, and parity) will not affect variation of sexual dimorphism in WHR. Therefore, we build two data sets from the national sample. Thus, in Filtered data set we filtered out some entries to consider these effects. From the original sample (N = 194,924), we selected the adults (individuals aged 18 and older; N = 124,578). Of them, only some were measured for height, weight, waist, and hip (N = 39,684, N_{male} = 17,400, N_{female} = 22,284). We used the standard cut-off points defined by the Centers for Disease Control and Prevention (2001) to discard from our sample the effects of abnormal nutrition during development on adult WHR. Hence, we selected men taller than 162.5 cm (N = 11,197) and women taller than 150.9 cm (N = 13,103), nulliparous females only (N = 1,192), and males and females with a normal BMI (WHO, 2011). In total, we analyzed data for 2,821 males (M_{age} = 39.07, SD = 17.015) and 471 females (M_{age} = 25.76, SD = 6.638). We calculated the individual WHR (waist circumference/hip circumference), and we used the same variables we implemented for the international sample ($\text{WHR}_{\text{male}}/\text{WHR}_{\text{female}}$) to calculate sexual dimorphism of WHR at the state level.

We defined WHR variables ($\text{WHR}_{\text{female}}$, WHR_{male}, $\text{WHR}_{\text{male}}/\text{WHR}_{\text{female}}$) among adults ($N_{total}$ = 39,684, N_{male} = 17,400 N_{female} = 22,284) without using other filters (Adult data set). Differences between sexes in age and BMI across successive filters were analyzed by means of analyses of variance (ANOVAs).

We returned to the original sample (N = 194,924) to obtain the variables that may affect male mate choice. We defined the divorce-to-married ratio (DMR) as the ratio of divorced (N = 2,587) to married (N = 50,802) individ-

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uals, aged 12 and older in the sample. We calculated the DMR at the state level. The ASR for each state was the ratio of adult males (N = 58,612) to adult females (N = 65,966). In addition, we estimated three OSRs per state—physiological (OSR_{phy}), social (OSR_{soc}), and mixed (OSR_{mix}). First, to obtain the OSR_{phy}, we divided the number of males aged 12 and older in the sample (N = 70,895) by the number of females aged 12 to 49 (where the latter is the mean age of menopause commencement among Mexican females) that were not pregnant or breastfeeding (N = 21,021). Second, the OSR_{soc} reflects the number of available males, aged 12 and older, in the sample (N = 30,784) divided by the number of available females, aged 12 and older, in the sample (N = 35,979). We defined as available those individuals that were not legally in a relationship (i.e., single, divorced, separated, widows, and widowers). Finally, the OSR_{mix} was obtained by dividing the number of available males aged 12 and older in the sample (N = 30,784) by the number of available females aged 12 to 49 who were not pregnant or breastfeeding (N = 10,820).

To evaluate the differences between male and female WHR in each state, we used the same statistical procedures that were described for the international sample. We analyzed the interrelationships between the variables supposedly affecting male mate choice (DMR, ASR, and OSRs) with a series of Pearson product–moment correlation tests. As above, we also used Pearson product–moment correlation tests to evaluate their relationships with the WHR variables (WHR_{female}, WHR_{male}, WHR_{male}/WHR_{female}), in Filtered and Adult data sets.

Results

Our study included data for all 32 Mexican states.

Nulliparous, normal BMI, well nourished, well measured, adult data set (filtered data set). The overall means of WHR ranged between 0.78 and 0.91 (see Table 2). In Mexico, females had a lower WHR than did males. A Kolmogorov–Smirnov test showed a normal distribution of male and female WHRs in 16 states. In 15 of them, the two samples showed homoscedasticity and Student's t tests found sexual differences in all of them. The sample from Querétaro had heteroscedastic variances, but a Welch's t test revealed that the male WHR was significantly greater than the female WHR. In the 16 states where at least one of the sexes showed a nonnormal WHR distribution, a Kolmogorov–Smirnov test for two independent samples revealed that male and female WHRs differed significantly in 15 states. In Yucatán, however, these differences were not statistically significant (see Table 2).

The DMR displayed a positive correlation with sexual dimorphism, it correlated negatively with female WHR; and did not correlate with male WHR (see Table 3; see Figure 2). ASR and OSRs did not correlate with the sexual dimorphism of WHR, female WHR, or male WHR (see Table 3). Further, the DMR displayed a positive correlation with the ASR, the OSR_{phy}, the OSR_{soc}, and the OSR_{mix} (see Table 4).

Adult data set. Our analyses of adult data set showed sexual dimorphism to be positively associated with all variables that influence male mate choice (see Table 3).

Comparison of data sets. The mean sexual dimorphism of WHR in the filtered data set was greater than in the adult data set, and this difference was statistically significant ($M_{filtered}$ = 1.094 ± 0.023, N = 32, M_{adult} = 1.058 ± 0.01, N = 32, t_W = 600.000, p = .001). The filters decreased the male WHR ($M_{male;adult}$ = 0.943 ± 0.01, N_{male} = 32, $M_{male;filtered}$ = 0.894 ± 0.01, N_{male} = 32, t = −25.205, p = .001) and the female WHR ($M_{female;adult}$ = 0.892 ± 0.01, N_{female} = 32, $M_{female;filtered}$ = 0.817 ± 0.02, N_{female} = 32, t_W = 528.000, p = .001).

There was no significant difference in age between adult males and females that were correctly measured (see Table 5). The difference appeared when we filtered the height of males and females (see Table 5). From there, the difference remained through successive filters, including into the final data set (see Table 5).

Males and nulliparous females who were correctly measured and well nourished (i.e., before we selected entries by BMI) did not differ in their BMI (see Table 5). However, in the filtered data set (i.e., after we selected individuals with normal BMI), females had a lower BMI than males (see Table 5).

Table 2
Summary of Data and Analyses: National Sample

State		WHR													
		Male			Female			Sex differences							
Name	Code	M	N	SD	M	N	SD	$M_{\text{male/female}}$	$M_{\text{male}-\text{female}}$	Statistic	DMR	ASR	OSRphy	OSRsoc	OSRmix
Aguascalientes	AS	.89	114	.07	.80	32	.06	1.12	.09	$t_S = 63.75, p < .05^*$	.03	.90	3.20	.85	2.71
Baja California	BC	.90	81	.22	.82	14	.09	1.10	.08	$z_{K\text{-}S} = 1.55, p = .01^*$	.05	.98	4.24	1.05	3.73
Baja California Sur	BS	.89	71	.06	.80	10	.08	1.11	.09	$t_S = 23.00, p < .05^*$	.04	1.00	3.67	1.00	3.37
Campeche	CC	.87	57	.06	.80	12	.08	1.08	.06	$t_S = 17.12, p < .05^*$	.01	.89	3.12	.92	2.72
Chiapas	CS	.90	82	.07	.83	12	.05	1.09	.07	$t_S = 25.38, p < .05^*$	.02	.84	3.09	.79	2.40
Chihuahua	CH	.91	98	.07	.81	15	.07	1.12	.10	$z_{K\text{-}S} = 2.70, p < .00^*$	.04	.94	4.00	.90	3.33
Coahuila	CL	.89	129	.07	.83	18	.06	1.08	.07	$z_{K\text{-}S} = 2.35, p < .00^*$	.03	.96	3.45	.96	2.96
Colima	CM	.89	94	.07	.81	20	.05	1.10	.08	$t_S = 41.99, p < .05^*$	.04	.91	3.27	.91	2.86
Distrito Federal	DF	.90	82	.07	.81	18	.07	1.11	.09	$z_{K\text{-}S} = 2.69, p < .00^*$	.06	.86	4.01	.77	3.32
Durango	DG	.91	102	.07	.81	21	.06	1.11	.09	$z_{K\text{-}S} = 2.65, p < .00^*$	.03	.92	3.88	.92	3.36
Guanajuato	GT	.87	100	.06	.81	17	.07	1.08	.07	$t_S = 30.92, p < .05^*$	.03	.85	3.58	.80	3.01
Guerrero	GR	.90	78	.05	.85	12	.05	1.06	.05	$t_S = 19.84, p < .05^*$	.01	.82	2.98	.80	2.53
Hidalgo	HG	.90	72	.07	.81	12	.06	1.11	.09	$z_{K\text{-}S} = 1.74, p < .00^*$	.03	.81	2.90	.77	2.45
Jalisco	JC	.89	100	.06	.82	22	.11	1.08	.06	$z_{K\text{-}S} = 2.44, p < .00^*$	.02	.94	3.54	.92	3.25
México	MC	.88	98	.06	.81	6	.03	1.09	.08	$t_S = 25.43, p < .05^*$	.02	.90	3.57	.81	2.96
Michoacán	MN	.89	108	.06	.82	15	.04	1.09	.07	$t_S = 38.92, p < .05^*$	.02	.86	3.30	.84	2.63
Morelos	MS	.89	87	.07	.78	15	.05	1.14	.11	$z_{K\text{-}S} = 2.96, p < .00^*$	.02	.84	3.21	.76	2.54
Nayarit	NT	.89	91	.11	.83	17	.17	1.07	.06	$z_{K\text{-}S} = 1.45, p = 03^*$	.03	.93	3.38	.90	3.08
Nuevo León	NL	.91	87	.07	.80	13	.08	1.14	.11	$t_S = 36.62, p < .05^*$	.03	.95	3.74	.96	3.16
Oaxaca	OC	.89	62	.06	.84	9	.03	1.05	.05	$z_{K\text{-}S} = 1.55, p = .02^*$	.01	.79	2.85	.76	2.46
Puebla	PL	.89	64	.07	.84	7	.06	1.06	.05	$z_{K\text{-}S} = 1.53, p = .02^*$	.01	.82	3.40	.79	2.83
Querétaro	QT	.90	97	.07	.81	19	.04	1.11	.09	$t_W = 7.01, p < .05^*$	.03	.89	3.18	.85	2.80
Quintana Roo	QR	.89	40	.08	.82	8	.04	1.09	.07	$z_{K\text{-}S} = 1.88, p < .00^*$	.02	.91	3.05	.94	2.68
San Luis Potosí	SP	.89	107	.06	.81	14	.03	1.10	.08	$z_{K\text{-}S} = 2.71, p < .00^*$	.01	.88	3.27	.91	2.83
Sinaloa	SL	.89	112	.06	.84	12	.16	1.05	.05	$z_{K\text{-}S} = 1.74, p < .00^*$	.03	.93	4.25	.97	3.68
Sonora	SR	.89	124	.07	.80	14	.08	1.11	.09	$t_S = 33.97, p < .05^*$	.04	.95	3.78	.94	3.17
Tabasco	TC	.89	75	.06	.80	11	.04	1.11	.09	$z_{K\text{-}S} = 2.28, p < .00^*$	.02	.88	3.10	.83	2.36
Tamaulipas	TS	.91	93	.06	.81	10	.05	1.11	.09	$t_S = 36.51, p < .05^*$	.03	.93	3.46	.91	3.01
Tlaxcala	TL	.91	91	.06	.85	28	.06	1.07	.06	$t_S = 34.34, p < .05^*$	.01	.83	2.96	.75	2.18
Veracruz	VZ	.89	68	.06	.82	16	.05	1.08	.07	$t_S = 29.95, p < .05^*$	.02	.86	3.04	.85	2.59
Yucatán	YN	.89	37	.09	.81	8	.06	1.10	.08	$z_{K\text{-}S} = 1.27, p = .07$ NS	.02	.89	3.11	.83	2.52
Zacatecas	ZS	.89	120	.07	.82	14	.05	1.08	.07	$t_S = 32.84, p < .05^*$	.02	.87	3.52	.85	2.90

Note. State code (Instituto Nacional de Estadística y Geografía, 2015); WHR = waist-to-hip ratio; M_{male} = mean of male WHR; N_{male} = male sample size; SD_{male} = SD for males; $M_{♀}$ = mean of female WHR; N_{female} = female sample size; $SD_{♀}$ = SD for females; $M_{\text{male}}/M_{\text{female}}$ = male WHR relative to female WHR; $M_{\text{male}}-M_{\text{female}}$ = sexual difference in WHR; t_S = Student's t; t_W = Welch's t; $z_{K\text{-}S}$ = Kolmogorov-Smirnov's; z; p = associated probability; * = statistically significant; NS = statistically nonsignificant; DMR = divorced-to-married ratio; ASR = Adult Sex Ratio; OSR_{phy} = physiological Operational Sex Ratio; OSR_{soc} = social Operational Sex Ratio; and OSR_{mix} = mixed Operational Sex Ratio.

Discussion

The aim of this research was to deepen our knowledge of the evolution of human sexual dimorphism in WHR through male mate choice. We presented published data at international and national levels from several human groups to test if (a) sexual dimorphism in WHR varies across human groups; and (b) changing conditions for male mate choice occurrence by means of DMR are concomitant to sexual dimorphism in WHR. Our results suggest that male mate choice may contribute to variations in sexual dimorphism across human groups.

Results from the international and national samples revealed that females had a lower WHR than males. This pattern suggests a sexual selection of the trait.

It is a widespread idea that, in humans, WHR is universally a sexual secondary trait. As stated by sexual selection theory, we expected sexual difference in WHR to be variable across human groups. Our studies support this expectation. In fact, the large combined effect size of the international sample cannot be explained by sampling error within a country-sample. To a certain extent, it could be explained by differential sexual dimorphism across countries. At first

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Table 3
Summary of Correlative Analyses Among Variables Potentially Affecting Male Mate Choice and WHR Variables: National Sample

Variables affecting male mate choice	Data set: Nulliparous, normal BMI, well nourished, well measured, adult			Data set: Adult
	WHR_{male}/WHR_{female}	WHR_{male}	WHR_{female}	WHR_{male}/WHR_{female}
DMR	$r = .584$, $p < .001$, $N = 32^*$	$r = .331$, $p = .064$, $N = 32$	$r = -.466$, $p = .007$, $N = 32^*$	$r = .521$, $p = .002$, $N = 32^*$
ASR	$r = .358$, $p < .051$, $N = 32$	$r = .125$, $p = .497$, $N = 32$	$r = -.321$, $p = .073$, $N = 32$	$r = .590$, $p < .001$, $N = 32^*$
OSR_{phy}	$r = .228$, $p = .210$, $N = 32$	$r = .233$, $p = .199$, $N = 32$	$r = -.127$, $p = .490$, $N = 32$	$r = .359$, $p = .044$, $N = 32^*$
OSR_{soc}	$r = .163$, $p = .372$, $N = 32$	$r = .077$, $p = .677$, $N = 32$	$r = -.145$, $p = .430$, $N = 32$	$r = .462$, $p = .008$, $N = 32^*$
OSR_{mix}	$r = .156$, $p = .394$, $N = 32$	$r = .132$, $p = .471$, $N = 32$	$r = -.104$, $p = .572$, $N = 32$	$r = .401$, $p = .023$, $N = 32^*$

Note. r = Pearson correlation coefficient; p = associated probability; * = statistically significant; DMR = divorced-to-married ratio; ASR = Adult Sex Ratio; OSR_{phy} = physiological Operational Sex Ratio; OSR_{soc} = social Operational Sex Ratio; OSR_{mix} = mixed Operational Sex Ratio.

sight, sexual difference in WHR seems to be present worldwide because in most of sampled countries the difference in WHR between males and females was both statistically and practically significant. However, supporting our expectation, there were several countries where there was no statistically significant sexual difference in WHR. In some of these, the corresponding effects sizes were low, suggesting no practical significance. In the Cook Islands, size effect was moderate. In short, sexual dimorphism in WHR across countries had different practical significance. It is possible that in countries where size effect was small, a larger sample size is needed. However, among countries showing large effect sizes, there was a consid-

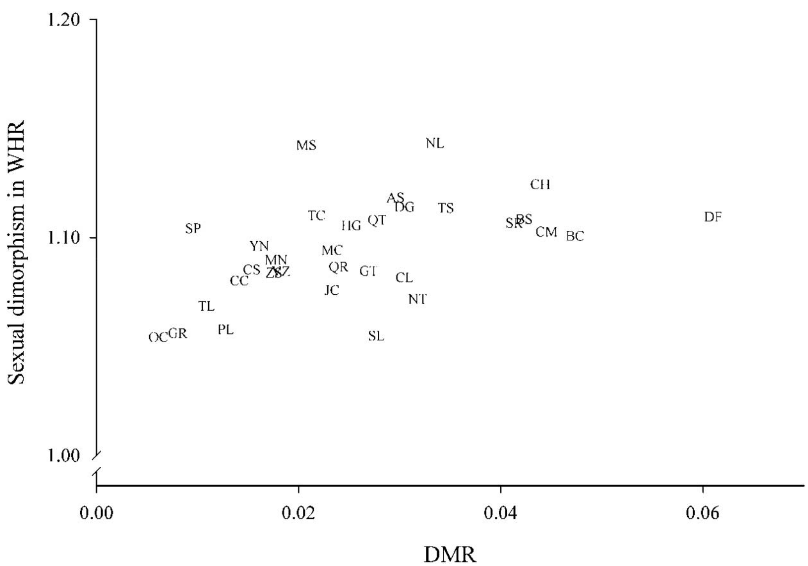

Figure 2. Positive correlation between divorced-to-married ratio (DMR) and sexual dimorphism in waist-to-hip ratio (WHR) at national level ($r = .584$, $p < .001$, $N = 32$). See Table 2 for codes.

Table 4
Summary of Correlative Analyses Among Variables Potentially Affecting Male Mate Choice: National Sample

	DMR	ASR	OSR_{phy}	OSR_{soc}	OSR_{mix}
DMR	—	r = .607, p < .001, N = 32*	r = .677, p < .001, N = 32*	r = .442, p = .011, N = 32*	r = .655, p < .001, N = 32*
ASR		—	r = .646, p < .001, N = 32*	r = .919, p < .001, N = 32*	r = .738, p < .001, N = 32*
OSRphy			—	r = .573, p < .001, N = 32*	r = .939, p < .001, N = 32*
OSRsoc				—	r = .714, p < .001, N = 32*
OSRmix					—

Note. $\text{WHR}_{♂}$ = male waist-to-hip ratio; $\text{WHR}_{♀}$ = female waist-to-hip ratio; $\text{WHR}_{♂}/\text{WHR}_{♀}$ = male WHR relative to female WHR; r = Pearson correlation coefficient; p = associated probability; * = statistically significant; DMR = Divorced-to-Married Ratio; ASR = Adult Sex Ratio; OSR_{phy} = physiological Operational Sex Ratio; OSR_{soc} = social Operational Sex Ratio; OSR_{mix} = mixed Operational Sex Ratio.

erable variation in sexual dimorphism. Moreover, in the two national data sets, the same variation of sexual dimorphism in WHR across Mexican states was found. At this point, variability of sexual difference in WHR across human groups suggests a subjacent sexual selective process depending on local circumstances (i.e., strengthening the intensity of sexual selection in groups with greater sexual dimorphism, compared to those with less sexual dimorphism). However, it remains to establish what kind of sexual selection may be

Table 5
Summary of ANOVA Tests for the Differences Between Sexes in Age and Body Mass Index (BMI) Across Successive Filters: National Sample

	Filters		
Variable	Adult males	Adult females	Statistic
Age	M = 42.60 SD = 17.652 N = 17,400	M = 42.74 SD = 16.528 N = 22,284	F = .642, p = .423, df = 1
	Well nourished, well measured M = 39.40 SD = 16.220 N = 11,197	Well nourished, well measured M = 38.82 SD = 14.659 N = 13,103	F = 8.654, p = .003*, df = 1
	Normal BMI, well nourished, well measured M = 39.07 SD = 17.015 N = 2,821	Normal BMI, nulliparous, well nourished, well measured M = 25.76 SD = 6.638 N = 471	F = 280.636, p < .001, df = 1
BMI	Well nourished, well measured M = 27.486 SD = 5.05 N = 11,197	Nulliparous, well nourished, well measured M = 27.196 SD = 6.794 N = 1,162	F = 3.234, p = .072, df = 1
	Normal BMI, well nourished, well measured M = 22.682 SD = 1.638 N = 2,821	Normal BMI, well nourished, well measured M = 22.120 SD = 1.655 N = 471	F = 47.419, p < .001, df = 1

Note. F = one-way analysis of variance (ANOVA) F-test statistic. M = mean; SD = standard deviation; N = number of individuals; p = associated probability; df = degrees of freedom.

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responsible of such intergroup variation of sexual dimorphism in WHR.

Previous studies have demonstrated that, at least in some human groups, there is a male preference for low female WHR (Furnham, Dias, & McClelland, 1998; Furnham, Tan, & McManus, 1997; Henss, 1995; Singh, 1993a, 1993b, 1994a, 1994b; Singh & Luis, 1995; Singh & Young, 1995). Accordingly, our results suggest that female WHR was the trait under sexual selection. In fact, as we predicted, the proportion of divorced individuals in both samples correlated positively with the sexual dimorphism in WHR, negatively with female WHR, and had no correlation with male WHR. These results are in line with the suggestion that "human mating strategies are unlikely to conform to a single universal pattern" (Brown, Laland, & Mulder, 2009, p. 297). The observed variation in human sexual dimorphism in WHR across population is in accordance with contemporary evolutionary theory of male mate choice. This selective process is expected under circumstances where the number of females that are available to an individual male for mating exceeds his capacity to mate with such females (Edward & Chapman, 2011).

In behavioral ecology, the variables usually used to operationalize the number of females that are available to an individual male for mating are sex ratios (i.e., ASR, and OSR; Emlen & Oring, 1977; Székely, Weissing, & Komdeur, 2014). In several animal species, these variables have demonstrated to be valuable in testing sexual selection predictions. In humans, the use of such variables seems to encounter some difficulties. For instance, Marlowe and Berbesque (2012) dealt with OSR in the Hadza hunter-gatherer tribe using mean values for length of birth interval, duration of estrus, and number of estrous cycles in females before conception. However, OSR, as they measured it, did not predict sexual dimorphism of body mass in humans as it did for other species. The authors attributed this failure to the fact that, in human societies, male–male competition does not depend on physical encounters. An interestingly find was that they suggested that marriage dynamics and the ASR could be better predictors of sexual dimorphism. The complexity of human social and cultural aspects that may modulate behavior and alter circumstances needed for the occurrence of selective processes. New methods of operationalization of the concepts of mate availability may help to gain accuracy upon such aspects.

We assumed that changing conditions for male mate choice occurrence could be operationalized by means of the number of divorced individuals relative to the number of married individuals. This assumption may raise several methodological concerns. For instance, DMR accounted for individuals who, at least once in their life, were married. Independently of the actual marital status (i.e., divorced or married), this condition excluded those individuals who were not available as mates for different reasons that can be social and culturally mediated. In fact, DMR excluded from the analysis individuals who lived a Catholic religious life (i.e., monks and nuns). However, other variables also have important limitations. Consequently, each of them provokes uncertainty. In our analysis, for instance, ASR and OSR_{soc} were computed from legal adult age, which may have excluded a large amount of sexually active individuals. OSR_{mix} and OSR_{phy} excluded females based on physiological age-linked variables (i.e., mean age at menarche and mean age at menopause) and physiological status (i.e., pregnant and breast-feeding), but did not estimate in any way the number of sexually inactive adult males, probably overestimating the number of males counted.

The outcome of our approach seems to favor DMR over sex ratios. Two aspects of the relationships found may support this interpretation.

First, there were dissimilarities among sex ratios regarding their biases (i.e., a slight female bias in ASR and OSR_{soc} vs. a moderate male bias in OSR_{phy} and OSR_{mix}). According to classical interpretations, dissimilar biased in sex ratios would affect mate choice in different ways. Contrary to evolutionary expectations, however, our results did not show differences between the ways that female biased sex ratios correlated to sexual dimorphism and the way male biased sex ratios did. Instead, DMR showed the correlations with sexual dimorphism in WHR, female WHR, and male WHR that we predicted. We made no explicit prediction regarding sexual biases in DMR. Nevertheless, in DMR, for every married male, there was a married female; and for every divorced male, there was a divorced female. There could not be sexual bias among married individuals (i.e., same-sex marriage was not legal in Mexico at

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the time of the data collection). Therefore, any bias in DMR would be because of a sex-bias in remarriage. In this regard, DMR was positively correlated with sex ratios, showing that divorces increased with increasing number of males available to mate (as well as increasing female scarcity). In this scenario, females could initiate more divorces and be more willing to remarry than males. However, there are studies showing that remarriage is more frequent in males than in females (Chamie & Nsuly, 1981; Coleman, Ganong, & Fine, 2000). More studies should address sexual differences in willingness to divorce. The positive correlation between DMR and sex ratios could also be expected from a female biased DMR (i.e., more divorced females than males).

Second, these results may stem from the effects of cultural practices on all of the variables that influence the relationship between female availability and male mate capacity. Social factors, such as gender differences in remarriage, can increase the number of females that are available for a male to mate. In Mexico, for instance, it is socially accepted that males look for a female partner of their own age or younger. In contrast, females typically seek a partner of their own age or older, as revealed by an analyses of national data performed by Sosa-Márquez (2014). This fact increases the age range of females from whom a male can choose a mate. The same is likely to happen in other societies where males are more inclined to remarry than females (Chamie & Nsuly, 1981; Coleman, Ganong, & Fine, 2000). Moreover, the OSR can be also be modified by sex related emigration patterns, as is the case in many rural Mexican towns, where adult males migrate more frequently than adult females (Barrera & Oehmichen, 2000). In these circumstances, the ability of males to mate is likely to be smaller than the number of available females. Therefore, our OSRs may have underestimated the number of females available to a male. A likely explanation is that, in humans, OSRs may be subject to the influence of such cultural factors as moral judgments against marrying a divorced individual, or mating with a married one. Finally, social practices may affect ASR in a similar way to OSR.

We suggest that, under certain social and cultural circumstances, DMR could reflect the conditions where male reproductive strategies are occurring (i.e., including male intrasexual competition, male mating effort, and male mate choice frequency, among others; Edward & Chapman, 2011).

Our results suggest that female WHR is a trait under strength-variable selection by male mate choice across human groups. In fact, as we predicted, the proportion of divorced individuals in both samples correlated positively with sexual dimorphism in WHR, negatively with female WHR, and had no correlation with male WHR. This result was predicted by the evolutionary theory of male mate choice and gender differences reported in remarriage rate. Our results could be added to subsequent findings suggesting the presence of several factors influencing the male mate choice sexual process driving female WHR (Sugiyama, 2004; Wetsman & Marlowe, 1999; Yu & Shepard, 1998). In fact, apart from the availability of direct information about mate quality (Yu & Shepard, 1998), difficulty of ecological conditions (Wetsman & Marlowe, 1999), and the local adjustments of preference to traits (Sugiyama, 2004), our study adds the possibility of changes in the strength of male mate choice. However, the correlative nature of our analyses does not allow asserting any causal relationship among the variables. For instance, it is possible that females with a lower WHR will divorce more frequently than do females with a higher WHR. Nevertheless, considering all previous evidence of male preference for certain values of female WHR (Furnham, Dias, & McClelland, 1998; Furnham, Tan, & McManus, 1997; Henss, 1995; Singh, 1993a, 1993b, 1994a, 1994b; Singh & Luis, 1995; Singh & Young, 1995), the six correlations that were found suggest that human sex differences in WHR are associated with the frequency of the male mate choice of WHR in females. To gain certainty on the selective process, it would be necessary to provide evidence for a positive relationship between the number of divorces, and the actual preferences of males for certain values of female WHRs.

Although divorce is currently legal in nearly every country, the guidelines that have prevailed locally over the past centuries appear to be related to the sexual dimorphism of WHRs. Countries that, until recently, have abolished

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the prohibition of divorce, show minor differences between the sexes when compared to those countries where the constitutional legislation have long allowed divorce. Further, countries where regulations concerning parental responsibility are effectively applied, there is a broad difference between male and female WHR. For instance, sexual dimorphism in WHR was lower in Italy, where the divorce law dates from 1974 (González & Viitanen, 2009), than in Denmark, where divorce law dates from the first half of the 20th century (González & Viitanen, 2009; Lund-Andersen & Krabbe, 2002), or in Turkey, where divorce law dates from 1926 (Rheinstein, 1953). Divorce rates in Mexico are low compared to those of other countries. Such stability is explained by an ideology that favors family unity and that is reflected in the restrictive practice of divorce law and the social rejection of divorced people. The distinct stability of the Mexican family is under pressure from rising divorce rates. This trend is particularly noticeable in northern Mexico, where the highest divorce rates are found (de la Peña & González, 1992). This is the case of Chihuahua, Baja California, and Baja California Sur.

Successive filters we imposed to assure that covariables of WHR (i.e., body mass, age, early developmental stuntedness, and parity) would not affect variation of sexual dimorphism in WHR affected analyses. The Filtered data set considerably reduced the sample size, while the Adult data set did not. The increasing effect of the filters on the sexual differences in WHR could be the result of an increase in male WHR, but also by a decrease in female WHR. In our data, the filters decreased the WHR of both males and females. Therefore, we attribute the increase in sexual dimorphism to a decrease in female WHR. In turn, there are two possible explanations for this reduction. The nulliparity restriction could reduce the mean age of the females in the sample, and consequently, the mean WHR. The selection of the individuals with normal BMI could also reduce the mean WHR. However, neither affected the main result (i.e., the positive correlation between the DMR and sexual dimorphism in the WHR). The age difference between the sexes of the two national data sets, indeed, depended on the filters. The difference appeared when we discarded the effects of abnormal nutrition during development, not when the criterion of nulliparity was applied. From there, the difference remained through the successive filters, including into the final data set. Concerning BMI, before we applied this selection, males and nulliparous females did not differ in BMI. However, after we selected individuals with normal BMI, females had a lower BMI than males. This means that differences in sexual dimorphism of WHRs between the two national data sets are probably because of the well-known effect of BMI on WHR. The age and BMI differences could have an impact on the correlation between sexual dimorphism and the DMR. However, neither could change the correlation between the female WHR and the DMR in the national sample. Moreover, in the nonfiltered data set, where there were no age differences among sexes or filter for BMI, the expected positive correlation between the DMR and sexual dimorphism in WHR was also found. Therefore, the main results seem to not have been affected by age differences between the sexes or the selection of individuals with normal BMI.

At a theoretical level, the present study contributes to orient evolutionary approaches on human behavior toward the integration of social and cultural aspects concomitants to variation in traits and selective processes. At a practical level, our study shows new ways to make operational concepts of human behavioral ecology.

For international and national samples, the means of WHRs for both sexes fell within recommended health values (WHO, 2011). This distribution seems to be contained within a range. Thus, it may reflect a stabilizing natural selection, independent of, and previous to, sexual selection. This finding supports a previous claim that human female WHR can be considered an honest signal of the quality of a female mate (Singh, 1993a). In comparison with the national sample, the international sample showed a larger range of WHRs. This difference is probably because, in the international sample, data from Mexico are near the middle.

Conclusion

These studies demonstrate that sexual dimorphism in WHR varies concomitant to DMR across human populations. This finding supports the hypothesis that human male mate choice is a circumstantially conditioned selective process responsible for such dimorphism and suggests that cultural and social aspects are potentially powerful to examine in detail the factors capable of strengthening or weakening the selective process. However, more studies are needed to explore this suggestion.

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