Waist-to-Hip Ratio Versus Body Mass Index As Predictors of Fitness in Women

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The claim that men prefer women with low waist-to-hip ratios (WHR) has been vigorously disputed. We examine self-report data from 359 primiparous Polish women (with normal singleton births and healthy infants) and show that WHR correlates with at least one component of a woman's biological fitness (her first child's birth weight, a variable that significantly affects infant survival rates). However, a woman's Body Mass Index (BMI) is a better predictor of her child's neonatal weight in small-bodied women (<54 kg). The failure to find a preference for low WHR in some traditional populations may thus be a consequence of the fact that, even in western populations, body mass is a better predictor of fitness in those cases characterized by low maternal body weight.

KEY WORDS: Body Mass Index (BMI); Fitness; Neonatal weight; Waist-to-Hip Ratio (WHR)

It has been suggested that men value attractiveness in women because it is a reliable cue to a woman's reproductive value (Buss 1989; Pawłowski and Dunbar 1999; Symons 1979). One trait that has received particular emphasis in this respect is waist-to-hip ratio (WHR), the trait that describes the classic hourglass shape in women (Henss 1995, 2000; Singh 1993a, 1993b). Most studies have reported a negative relationship between WHR and attractiveness, with attractiveness ratings peaking at WHR values of around 0.7 (albeit with declining attractiveness at values below 0.7). Rozmus-Wrzesinska and Pawłowski (2005) have recently shown that this effect is largely due to changes in waist size rather than changes in hip size.

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The claim that male preference for low WHR is a cross-cultural trait in humans (Furnham et al. 1997; Singh 1993a) has, however, been disputed. Some authors (e.g., Tovée et al. 1997, 1999, 2000) have argued that studies of the influence of WHR on women's attractiveness are methodologically flawed, the claimed effect being an artifact of the influence of body mass index (BMI: the ratio of mass/stature^2). Tovée et al. (1999) analyzed data from a sample of UK women and found that, although WHR had some predictive value, BMI was a significantly better predictor of males' preference ratings. Others have argued that the apparent universality of this preference for low WHR merely reflects the pervasiveness of the visual media and the peculiarities of western cultural interests. Wetsman and Marlowe (1999; Marlowe and Wetsman 2001) and Yu and Shepard (1998), for example, found that WHR was not a reliable predictor of men's ratings of women's attractiveness in two separate hunter-gatherer societies.

However, the force of at least some of these criticisms has subsequently been questioned. Streeter and McBurney (2003), for example, have recently shown that, contrary to Tovée et al.'s (1999, 2000) repeated assertions, a woman's WHR does in fact influence her attractiveness, even when the effect of weight on attractiveness judgments is removed. Similarly, a recent review of cross-cultural data by Furnham et al. (2002) has tended to support the claim that WHR is a widely (even if not necessarily universally) used cue of women's attractiveness. More importantly, perhaps, Sugiyama (2004) was able to show that Amazonian Shiwiar hunter-gatherer men used both WHR and body weight as cues of attractiveness, but did so in a context-sensitive manner.

A more serious issue, however, is that some authors have questioned whether variation in WHR corresponds to variation in biological or reproductive quality (Tassinary and Hansen 1998). Since the claim that WHR is correlated with fertility is fundamental, this criticism is, in many ways, much more serious. It is generally accepted that the waist-to-hip ratio reflects fat distribution in women: low ratios reflect relatively heavy fat deposition around the buttocks and thighs, thereby emphasizing the narrowness of the waist. There is empirical evidence to suggest that WHR correlates with proximate physiological factors such as health (Björntorp 1988; Folsom et al. 1993; Leibel et al. 1989; Singh 2002) and female reproductive endocrine titre (DeRidder et al. 1990; Jasienska et al 2004). Visceral fat in the waist region, for example, can be a signal of higher morbidity risk (Lin et al. 2002; Misra and Vikram 2003). WHR has also been found to correlate negatively with the level of sex steroids and gonadotropins, and positively with the timing of puberty in girls (Zaadstra et al. 1993). Health and endocrine status can be expected to correlate directly with a woman's reproductive potential. In addition, there is some evidence from artificial insemination programs to suggest that WHR may be directly correlated with fecundability, and hence biological fitness. Zaadstra et al. (1993), for example, found that the probability of successful pregnancy decreased dramatically in women with high WHR. Similarly, Wass et al. (1997) reported that the success rate for *in vitro* fertilization involving embryo transfer was significantly influenced by WHR (but not BMI), even after controlling for age, body mass index, smoking, indication for *in vitro* fertilization, parity, and number of embryos transferred. More recently, Yamamoto et al. (2001) have demonstrated a positive correlation between WHR and the occurrence of preeclampsia (a condition associated with high blood pressure and toxaemia that develops in mid-pregnancy and can be fatal to both fetus and mother if untreated), a relationship they found to be independent of BMI and body weight. Finally, women with polycystic ovaries usually have lower levels of estrogens and higher levels of testosterone and a higher WHR (Remsberg et al. 2002).

In addition, high WHR and low body mass index (BMI) may be related to the late onset of reproduction (age at first live birth) (Kaye et al. 1990), and hence to a shorter reproductive lifespan (probably the single most important factor influencing lifetime fitness in mammals: Clutton-Brock 1988). Low BMI (as reflected in, for example, anorexia) is, of course, also associated with poor health, cessation of menstrual cycling, and low chances of conception (Voland and Voland 1989), whereas high BMI may reflect the availability of energy reserves for pregnancy and, especially, lactation. Although both indices are typically subject to marked reductions in fertility at extreme values, our concern here is with mid-range values where all individuals can be deemed healthy and broadly fertile.

On balance, then, there is considerable evidence to suggest that, occasional claims to the contrary, WHR *does* correlate both with aspects of health and (independently, or as a consequence of poor health) with fertility. Since this evidence derives from medical studies that were not concerned with the evolutionary aspects of attractiveness, these findings would seem to be above reproof. In this study, we take this analysis one stage further by seeking to determine, for a sample of contemporary European women, whether body shape influences reproductive fitness rather than just fertility. Birth weight is the single most important predictor of infant mortality (Chase 1969; Fields and Frisancho 1993; Koops et al. 1982; McCormick 1985; Sappenfield et al. 1987) as well as morbidity (DeScrilli et al. 1983; Najmi 2000; Scott et al. 1981; Spinillo et al. 1994), both in modern industrial societies and in traditional societies. It thus provides an index of one key component of biological fitness in humans (see also Pawłowski 1998). Preeclampsia, for example, is particularly prevalent in low birth weight pregnancies. Similarly, there is now an extensive literature linking low birth weight to a wide range of clinical conditions that threaten life in adulthood (Godfrey and Barker 2001; Moor and Davies 2001). We use birth weight here as a proxy for fitness in order to ask whether WHR or any other relevant anthropometric indices are good predictors of a woman's reproductive capability.

METHODS

The data derive from 728 women (aged 16–47) who attended at 10 pediatric outpatient clinics and 5 primary care clinics in Wrocław (Poland) between spring 1998 and spring 1999. To ensure homogeneity of the sample, only mothers with healthy babies aged between 9.75 months and 15.5 months who lived in Wrocław and were visiting the clinic for routine pediatric checks were included in the sample. Because very high neonate weight (>4.2 kg) is a risk factor (Xiong et al. 2000), 15 infants with birth weights exceeding 4.2 kg were excluded from the analyses (although, in practice, with such a small number relative to sample size, including them does not change the results of the statistical analyses or the conclusions). In addition, 245 multipares (including cases of twins) were excluded because parity influences body shape; a further 109 cases were excluded because the mother could not recall the exact gestation length (21 cases), pre-pregnant waist or hip girths (56 women), pre-pregnant body weight and/or height, or failed to give their age (32 women). These deductions left 374 primiparous mothers who produced singleton, healthy infants and provided numerically precise values for the variables we requested; only data from these women are used in the present analysis. Apgar scores were available for all except 10 of these infants: 92.5% had scores of 8 or better (indicating normal, healthy infants at birth).

At the clinics, mothers were interviewed to collect data on key variables: baby's weight at birth, gestation length, and sex; mother's pre-pregnant minimum waist and maximum hip girths (from which we calculated her waist-to-hip ratio, WHR); and her pre-pregnant body weight and height (from which we determined her body mass index, BMI, defined as kg/m^2). Gestation length is known to be an important factor influencing neonate weight, and is thus likely to be a significant confounding variable unless controlled for. Although recall data will obviously be subject to error, we endeavored to reduce this risk by including data only from mothers who gave birth within the preceding 16 months and gave figures for all variables. There is evidence that women (and especially overweight and tall women) may underestimate their self-report anthropometric measurements (see review by Engstrom et al. 2003), and this could clearly be a problem. Self-report of anthropometry is a common paradigm in epidemiological studies, and a large number of studies have been carried out to check the accuracy of such data: comparison of self-report values with those obtained by technicians typically yields significant correlations in the order of 0.70–0.99 (with sample sizes of 66–227 women) for hip and waist circumferences (Freudenheim and Darrow 1991; Hall and Young 1989; Kushi et al. 1988; Rimm et al. 1990; Weaver et al. 1996). However, even if some residual error remains, there is no reason to expect the magnitude of such errors to be correlated with infant natal weight; at least one study of European women found no correlation between stature and a number of relevant measures of body fat (including waist circumference) (Han et al. 1997). More importantly, in the present case, participants were not aware of the aim of the study and so could not have introduced any covert biases into their responses.

RESULTS

Table 1 gives the descriptive statistics for the sample. Controlling for newborn sex, maternal age, and gestation time, partial correlation analysis shows that mother's height and pre-pregnant WHR are both significant predictors of neonate weight (Table 2). The correlation coefficient for WHR is negative, as predicted. We included mother's hip circumference in the analysis to check whether the WHR effect was due to hip size alone or to relative fat distribution around hips and waist. The lack of a significant effect for hip size indicates that the WHR effect is due to relative fat distribution rather than to hip size per se. For the sample as a whole, BMI does not have a significant influence on

Table 1. Descriptive Statistics for the Sample of Mothers (181 with male infants, 193 with female infants)

	Mean	*s.d.*	*Range*
Birth weight (kg)			
Males	3.44	0.51	1.7–4.8
Females	3.27	0.48	1.1–4.9
Gestation (weeks)	39.5	1.68	31–44
Maternal BMI	21.1	2.6	16–33.6
Maternal WHR	0.75	0.06	0.60–1.12
Maternal age at infant's birth (years)	24.9	4.6	15.7–47.1
Maternal stature (m)	1.65	0.05	1.50–1.86

Table 2. Partial Correlations with Neonate Birth Weight (in g) as the Dependent Variable, Controlling for the Sex Difference in Neonate Weight ($N = 359$ women with neonates ≤ 4.2 kg)

	Standardized β	*Partial correlation*	t_{351}	*P*
Mother's age (years)	0.09	0.107	2.02	0.044
Mother's height (cm)	0.21	0.220	4.22	<0.001
BMI	0.09	0.072	1.35	0.178
WHR	–0.13	–0.114	–2.15	0.032
Hip girth (cm)	–0.07	–0.048	–0.91	0.365
Sex of infant	–0.19	–0.222	–4.27	<0.001
Gestation time (weeks)	0.45	0.472	10.04	<0.001

neonate weight. Although there is a weak correlation between BMI and WHR in our sample (r = 0.22, t_{372} = 4.26, p < 0.0001), when this effect is partialled out the analysis confirms that the relationship with WHR is independent of any effect that BMI might have. Including the 15 large (>4.2 kg) infants does not influence these results.

We next ask whether the relationship between WHR and neonatal weight is dependent on the mother's pre-pregnant weight. We divided women into two weight classes using the lower quartile of body weight (54 kg) to differentiate light (N = 113) and heavier (N = 261) women. We then ran separate partial correlation analyses for each weight class. The results reveal that, of the two variables of interest here, only maternal BMI is a significant predictor of neonate weight in the small maternal weight group, whereas only WHR is a predictor for larger-bodied women (Table 3).

To explore this in more detail, we ran a series of multivariate analyses with neonate weight as the dependent variable and WHR and BMI as independent variables, controlling for maternal age, maternal height, and baby's sex, for mothers whose pre-pregnancy weight was below versus above a specified threshold. The threshold was allowed to vary, in steps of 5 kg, from 45 to 75 kg (sample size was too small to warrant analysis for women smaller than 45 kg or larger than 75 kg). At each threshold value, separate multiple regression

Table 3. Partial Correlations with Neonatal Birth Weight (in gm) as the Dependent Variable for Two Separate Maternal Weight Classes (controlling for the sex difference in neonate weight)

	Maternal Body Weight < 54 kg $F_{7,103}$ = 19.6, p < 0.0001 Multiple r = 0.76 N = 111			
	β	r	t_{103}	P
Gestation time (weeks)	0.59	0.663	8.98	<0.001
Mother's height (cm)	0.42	0.436	4.92	<0.001
Hip girth (cm)	0.01	0.01	0.12	NS
Prepregnant WHR	0.02	0.023	0.23	NS
BMI	0.21	0.234	2.45	0.016
Mother's age	0.05	0.069	0.70	NS

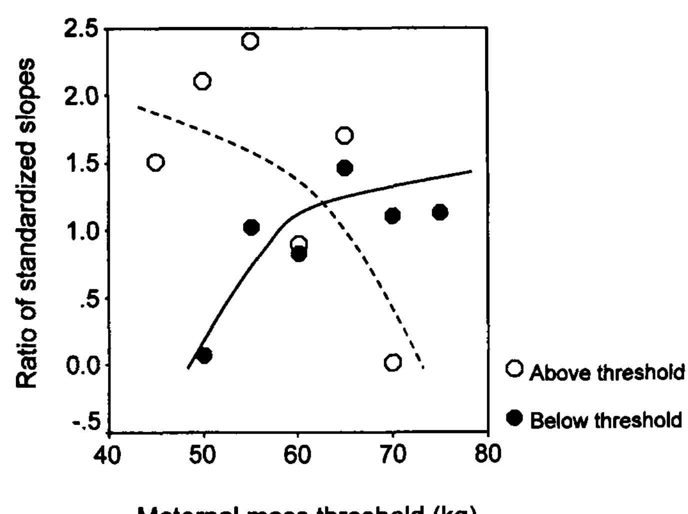
	Maternal Body Weight ≥ 54 kg $F_{7,240}$ = 9.19, p < 0.0001 Multiple r = 0.46 N = 248			
	β	r	t_{240}	P
Gestation time (weeks)	0.33	0.35	5.76	<0.001
Mother's height (cm)	0.11	0.11	1.66	NS
Hip girth (cm)	−0.1	−0.07	−1.03	NS
Prepregnant WHR	−0.22	−0.17	−2.74	0.007
BMI	0.07	0.05	0.82	NS
Mother's age	0.10	0.11	1.65	NS

equations were calculated for all subjects whose recorded body weight was below that threshold and for all those whose weight was above that threshold. To assess the relative impact of the two variables on neonate weight, we then calculated the ratio of the standardized slope coefficients (dividing the coefficient for WHR by that for BMI) for each weight threshold value: high ratios mean that WHR has relatively more influence than BMI, whereas low ratios mean that BMI has a bigger effect than WHR. Figure 1 shows that at low maternal weight BMI has more impact whereas at high maternal weight WHR has more impact, and that the relative influence of the two variables converges at intermediate maternal weight.

DISCUSSION

Our results indicate that WHR is a reliable predictor of offspring natal weight. However, they also indicate that, among small-bodied women within the same population, WHR can be a poor cue of a woman's reproductive potential and that, in these cases, body mass index (or even the mother's stature) may be a more reliable cue. Since infant survival is an important component of fitness (along with birth rate and reproductive lifespan) and neonatal weight has always been an important factor influencing infant survival (see Fields and Frisancho 1993; McCormick 1985), it necessarily follows that neonatal weight is a convenient proxy for fitness. The results reported herein thus suggest that

Figure 1. Relative impact of WHR and BMI (indexed as the ratio of standardized β coefficients of WHR/BMI) in a multiple regression analysis with neonatal weight as the dependent variable, controlling for maternal height, maternal age, and baby's sex. Solid symbols: mothers whose body mass was less than threshold value. Open symbols: mothers whose body mass was greater than threshold value. Subjects are primiparous women who produced infants weighing $\leq$4.2kg.



WHR (and, in appropriate cases, BMI) provides reliable cues to at least one important component of a woman's fitness. If men select women preferentially on the basis of their fitness potential (see, for example, Pawłowski and Dunbar 1999), then these are cues that they may well use in selecting potential mates.

There remain, of course, some potential confounding variables. Smoking, for example, is one of the most important factors influencing neonatal weight (Ellard et al. 1996; Zaren et al. 1997). Two observations, however, suggest that smoking is unlikely to be responsible for our results. First, there would have to be a correlation between smoking and stature, BMI, or WHR; the latter seems especially unlikely. In any case, Zaren et al. (1997) showed that BMI (along with a number of other variables) influenced birth weight independently of smoking history in a large sample of Scandinavian women. Second, in reality, the effects of smoke inhalation may be all but impossible to control, given Ellard et al.'s (1996) finding that passive smoking has a measurable effect on birth weight. Maternal body weight and stature are also possible confounding variables, since both are known to affect offspring birth weight (Karim and Mascie-Taylor 1997; Meis et al. 1997). However, although we could confirm the influence of both these variables in the present sample (see Table 2), the use of multiple regression allowed us to partial these effects out. Thus, it seems unlikely that these possible confounds could be responsible for the apparent relationship between WHR/BMI and birth weight.

A further factor to consider is that we truncated our sample at a birth weight of 4.2 kg. It is important to recognize that both mortality and morbidity rates increase significantly in very large babies (women who produce neonates greater than 4.2 kg in weight, for example, are more likely to experience both hypertension and preeclampsia: Xiong et al. 2000). Stabilizing selection of this kind is, of course, a common feature of biological systems and to be expected (with specific reference to stature in humans, see Nettle 2002a, 2002b). Our concern, however, has been to explore the possible relationship between anthropometric indices and neonatal weight (as a proxy for fitness), and the fact that such a relationship may be curvilinear in the extremes is distracting. For this reason, we discounted babies that were unusually heavy. However, the numbers involved were small (15 of a total of 374 babies that qualified on the remaining criteria, or just 4%), and censoring the data in this way did not in fact distort our conclusions.

Perhaps the most important finding from this study is the fact that WHR and BMI may be seen as alternative cues of mate quality that are themselves both influenced, in turn, by maternal body weight. We suggest that, when all other cues are held constant, men can choose to weight these two particular cues differentially relative to each other according to prevailing economic or health conditions (see also Kirchengast and Huber 2001; Sugiyama 2004). The fact that, within the same population, we can show that BMI is a better predictor of our proxy for fitness at one end of the body weight distribution and WHR a better predictor at the other end is, we believe, the first time that such a switch in the valencies of two cues has actually been demonstrated. Although far from surprising from an evolutionary point of view (variables that are influenced by several different factors often show this effect in biological systems: for examples, see Dunbar 1988), unequivocal examples of this in humans have perhaps been less common. In this case, the significance of this effect lies in the fact that it offers us a possible resolution of the dispute over which physical traits males prefer.

While the correlation between birth weight and WHR provides a clear vindication for the claim that WHR is a trait of choice for males, the finding that BMI is a better predictor of neonatal weight in small-bodied women seems to fit well with the evidence that, in at least some traditional cultures, fatness (in effect, BMI) may be seen as more attractive than low WHR (Sugiyama 2004; Wetsman and Marlowe 1999). Our results show that, in appropriate circumstances, it *is* a better index of fitness. Tassinary and Hansen's (1998) findings point in the same direction: they found that the perceived attractiveness of lower WHR was most pronounced in the moderate weight category in a U.S. student population, whereas the differences between women of different WHR in terms of both fecundity and attractiveness were less compelling in the light and heavy body weight categories.

It is worth noting that Brown et al. (1996) found a positive correlation between WHR and birth weight in a very heavily selected sample of 521 American women (selected from a population of 28,000 women). The women in their sample were older than ours (mean ages 29.3 vs 24.9 years, respectively), considerably heavier (means of 62.3 kg vs 57.5 kg), and produced heavier infants (means of 3.54 vs 3.30 kg); they had been selected principally because they were healthy mothers who had received early, regular prenatal care. In addition, Brown and colleagues measured waist and hip circumstances not as is conventional at their smallest and widest points, respectively, but rather at a specific anatomical point (2 cm above the navel and at the iliac spines, respectively).

In the more general context of mate choice, it may be worth noting in passing that maternal stature is revealed as a very significant effect (Table 2). Taller women produce larger babies (and should thus have higher fitness). Nettle (2002b) reported a hump-shaped relationship between number of children and stature in a cohort sample of British women, which was driven mainly by declining health (and hence fecundity) in very short women. To the extent that the present findings mirror the lefthand side of Nettle's graph, the present study lends support to his findings from a second population.

Our results thus suggest an explanation for why, in some tribal peoples such as the Hadza of East Africa and the Matsigenka of South America, men seem to prefer women with higher BMI rather than low WHR. Among the agropastoralist Kipsigis of Kenya, for example, men prefer brides with a (relatively) large physical frame precisely because they are less likely to suffer difficult childbirths (although, in this case, WHR was not included as a cue) (Borgerhoff Mulder 1988). Our results suggest that, in populations characterized by low body weight and low stature (as is typical of most tribal populations), WHR is likely to be a poor predictor of woman's reproductive potential. Instead, body mass index is a far better guide to reproductive potential. This is almost certainly because the energy resources available to the mother as metabolizable fat is the single most important factor influencing fetal and perilactational growth weight (and hence infant survival) in populations that live on the margins of survival. It should be noted that we adopt a neutral view as to whether the focus on WHR is a recent phenomeon in postagricultural (or even postindustrial) societies (and so reflects humans' natural abilities to recognise and exploit novel correlations found between environmental phenomena: see Dunbar 1995) or a reflection of what happens in traditional societies (and is of long-standing evolutionary occurrence).

In conclusion, we have shown that WHR *is* a reliable predictor of a woman's fitness (as measured by the weight of her primiparous newborn), but only among larger-bodied women. Body mass index is a better predictor than WHR when body size is small. This appears to explain why previous studies have found conflicting results, with men seeming to prefer large body size to low WHR in traditional societies but the reverse in modern, western societies. This switch in the predictor of fertility appears to be under the influence of economic/ecological conditions and their effect on adult body size, and it is significant that we have been able to demonstrate just such effects within a single population. Switches of this kind are far from uncommon in biology: economic conditions have been shown to have a significant impact, for example, on the relationship between reproductive output and female longevity in at least one historical European population (Lycett et al. 2000).

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