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Abdominal depth and waist circumference as influential determinants of human female attractiveness☆

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Abstract

Previous research based largely on two-dimensional (2D) line drawings and picture stimuli has established that both body mass index (BMI) and waist-to-hip ratio (WHR) influence the perceived attractiveness of human female bodies. Here, we extend these studies by (1) creating a more ecologically valid stimulus set consisting of 3D videos and 2D still shots from real female "models" rotating in space, and (2) measuring and examining the influence of several additional anthropometric variables that previously have not been considered. Multiple linear regression analysis revealed that the depth of the lower torso at the umbilicus, or abdominal depth, and waist circumference were the strongest predictors of attractiveness, stronger than either BMI or WHR. Women with shallow abdominal depth and small waist circumference are more likely to be healthy and nonpregnant, suggesting that this may be an adaptive male preference that has been shaped by natural selection. Leg length was a consistent positive predictor of attractiveness, perhaps because it has been correlated with biomechanical efficacy or healthy prepubertal growth that is unhindered by nutritional or energetic deficiency. Our results show that conclusions regarding anthropometric predictors of attractiveness are influenced by the visual perspective of the perceiver, as well as the anthropometric variables considered for analysis.

Keywords: Anthropometry; Attractiveness; Waist-to-hip ratio

1. Introduction

The association among physical attraction, mate choice and reproduction has prompted investigators to suggest that an understanding of physical attractiveness requires an evolutionary perspective that considers the likely selection pressures that shaped human mate choice (Gangestad & Scheyd, 2005; Singh, 2002). From this perspective, attractiveness should be related to fitness. Accordingly, males are expected to evaluate attractiveness of potential female mates on the basis of several criteria, including genetic quality, health, fertility and availability of resources to sustain pregnancy and lactation.

It has been argued that the ratio of waist-to-hip circumference is inversely related to health and fertility (Singh, 2002), as well as the availability of critical fat reserves needed to sustain fetal and infant brain development (Lassek & Gaulin, 2006, 2008). This has led to the hypothesis that men evolved preferences for female mates with low waist-to-hip ratios (WHR) (Singh, 1993). Initial investigations of this hypothesis presented participants with a group of line drawings of figures that varied in both weight and WHR, and asked them to choose which of the figures is most attractive (Singh, 1993). Men from a wide range of societies consistently express a preference for low WHR figures among women of normal body weight (Singh, 2002). Although these results appeared to support the hypothesis that men find low WHRs attractive, these initial studies were not without limitations. First, within the same

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weight category, figures with lower WHRs have smaller waists and will therefore also be perceived as lighter. Thus, it is not possible to determine whether the preference for a lower WHR figure is due to the ratio itself or the perceived reduction in body weight. In other words, WHR and body weight are confounded in this stimulus set (Tovee et al., 2002). Second, the stimuli have limited ecological validity, as they do not depict real women, and they do not afford a 3D perspective. Third, WHR is measured as a ratio of widths rather than circumferences, and it is the latter, not the former, that is correlated with fertility (Tovee et al., 2002). Finally, the preference for low WHR figures may not be universal, given that men in at least two traditional, non-Western societies reportedly do not express this preference (Wetsman & Marlowe, 1999; Yu & Shepard, 1998). However, it should be noted that one of these two groups, the Hadza hunter-gatherers, do express a preference for low WHR when the stimuli are shown in side rather than in front profile (Marlowe et al., 2005).

A subsequent study addressed several of these limitations by measuring the body mass index (BMI) and waist-to-hip circumference of real women and asking participants to rate their front-view photographs for attractiveness (Tovee et al., 2002). Using multiple linear regression, the authors assessed the independent effects of both BMI and WHR, and concluded that BMI was the stronger determinant of attractiveness of female bodies. The stimuli were more naturalistic than the previous line drawings, but still lacked a 3D perspective. This limitation was addressed in another study that used body scans from real women to create rotating 3D images that participants rated for attractiveness (Fan et al., 2004). Importantly, a wide range of measures in addition to BMI and WHR were included in regression models as potential predictors of attractiveness. Results showed that not BMI, but a variable that is highly correlated with it, the volume to height index (VHI), was the strongest determinant of attractiveness. Leg length and WHR were also significant predictors, but explained far less variance in attractiveness than VHI.

Here, we extend these studies in multiple ways. First, we assemble the most naturalistic, ecologically valid stimulus set yet, by creating videos of real women rotating in 3D space. Second, we include a large number of anthropometric measures that were not included in previous studies and that could potentially better account for attractiveness ratings than either BMI or WHRs. In particular, we include several anthropometric correlates of endocrine status, based on the hypothesis that men should be particularly sensitive to these cues to fertility. Finally, we assess the impact of using 2D vs. 3D stimuli as well as the impact of various 2D perspectives (front, side and rear) on assessments of attractiveness.

2. Methods

2.1. Stimuli

Forty-three female volunteers from the Emory University community (ages 18–24 years) were recruited via internet postings and fliers to serve as models from whom video stimuli would be created. Exclusion criteria included pregnancy, severe scoliosis, current fertility drug usage (but not oral contraceptive use) and a history of cosmetic surgery other than facial procedures. In an initial e-mail screening procedure, BMI of prospective models was calculated based on self-reported height and weight using the formula: BMI=weight in kilograms/(height in meters)^2. Models who fell outside the World Health Organization range for healthy size (BMI=18–24) were excluded based on Singh's assertion that the effect of WHR on attractiveness is greatest for women of normal body weight (Singh, 2002). All models who met the screening criteria were asked to participate in the study, following enrollment and consent protocols approved by the Emory University Institutional Review Board.

Enrolled participants then answered a questionnaire regarding oral contraceptive use, the number of days since their last menstrual period, and bra and cup size. Afterwards, they were asked to change into a form-fitting thin lycra leotard that matched their skin color. Anthropometric measures were chosen based on their presumed developmental and endocrine characteristics, as described in Table 1. Measurements were taken from each model in the following sequence: stature, acromial height (i.e., standing height of the acromion process at the tip of the scapula), sitting height, abdominal depth, shoulder width, pelvic width, mid-arm circumference, chest circumference (i.e., bust size), underchest circumference, waist circumference, hip circumference, length of second digit on each hand, length of fourth digit on each hand, weight and buttock height. Abdominal depth is an anterior-to-posterior measurement taken in the sagittal plane that reflects the depth of the lower torso at the umbilicus. Other measurements are described in the supplementary methods. Measurements were taken twice and repeated if they differed by more than 0.5 cm. Measurements were rounded down to the nearest 0.1 cm. From these measurements, additional variables were calculated, such as the ratio of waist-to-hip circumference, ratio of chest to underchest circumference, second to fourth digit ratio, leg-to-stature ratio and androgen equation, which is equivalent to three times the shoulder width minus one times the pelvic width (Tanner, 1990). Descriptive statistics for each of these variables are listed in Table 2. Correlations among several of these variables are listed in Table 3.

All models were videotaped while standing on a rotating stage with arms held perpendicular to the body, so that the abdominal area was not obscured. The circular wood stage mechanically rotated once every 8 s. After filming, which was done always from the same distance and angle, participants provided epithelial and blood spot samples for genetic and hormonal assays, respectively. Still shots of front, side and back views of each model also were taken from the video that was taken of them. Models' faces were blurred to protect confidentiality and to obviate any influence of facial appearance on attractiveness ratings.

Table 1
Developmental and endocrine characteristics of selected anthropometric measures

Measurement	Rationale
Abdominal depth	Negatively correlated with adult estrogen levels (Mayes & Watson, 2004)
Acromial height	Negatively correlated with pubertal timing (Pyle et al., 1961)
Chest-to-underchest ratio	Positively correlated with adult estrogen levels (Jasienska et al., 2004)
Hip circumference	Positively correlated with fat stores used in reproduction (Rebuffé-Scrivé et al., 1985)
Second to fourth digit ratio	Negatively correlated with the ratio of fetal testosterone to fetal estrogen, and adult estradiol (McIntyre et al., 2007; Lutchmaya et al., 2004)
Leg-to-stature ratio	Leg length is positively correlated with health and nutrition throughout childhood (Karlberg in Ulijaszek et al., 1998)
Mid-arm circumference	Positively correlated with body fat stores and peripheral fat patterning (Frisancho, 1990)
Pelvic width	Positively correlated with extent of estrogen exposure at puberty (Johnston in Ulijaszek et al., 1998) and fetal outcomes (Martyn et al., 1996)
Shoulder width	Positively correlated with extent of androgen exposure at puberty (Veldhuis et al., 2006)
Sitting height	Positively correlated with health and nutrition in infancy and puberty (Karlberg in Ulijaszek et al., 1998)
Stature	Positively correlated with pre-adult nutrition and health, and life expectancy (Grantham-McGregor et al., 2007)
Waist circumference	Negatively correlated with adult estrogen levels (Mayes & Watson, 2004)
Waist-to-hip ratio	Negatively correlated with adult estrogen and progesterone levels (Jasienska & Ziomkiewicz, 2004); positively correlated with androgens and health risk (Baghaei et al., 2003; Bjorntorp, 1996)
Weight	Positively correlated with energy stores and estrogen turnover (Frisancho, 1990; Longcope, 1996)
BMI	Curvilinear correlation with nutritional status (under- and overnutrition) and health (Flegal et al., 2005)

Front-, side- and rear-view still shots from one model, along with her attractiveness ratings, are shown in Fig. 1.

2.2. Blood spot estradiol measurements

We assay total 17β-estradiol with a 3-day ^{125}I radioimmunoassay protocol (Shirtcliff et al., 2000), using kit reagents from Diagnostic Systems Laboratories (Webster, TX, USA). No effort was made to measure estradiol at a particular cycle phase.

2.3. Participants and procedures

Forty-nine males (mean=21.7 years, S.D.=5.56, range=18–54 years) and fifty-six females (mean=21.7 years, S.D.=3.44, range =18–35 years) were recruited from the Emory University community to rate the 43 female models' videos and 2D still shots for attractiveness on a 10-point scale (1=*least attractive*, 10=*most attractive*). Female subjects were included to evaluate whether females could accurately predict male perceptions of attractiveness in female bodies. All participants were of self-reported heterosexual orientation.

E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA, USA; http://www.pstnet.com/products/e-prime/) was used for stimulus presentation. Stimuli were displayed on computer screens in a computer lab. Males were asked to rate how attractive they found the female models, whereas females were asked to rate the models based on how attractive they thought a heterosexual male would find them.

Prior to rating the stimuli, participants were shown five sample stimuli that were chosen to span the full range of our models' attractiveness to help them calibrate their ratings so that they would make use of the entire scale. Participants were also verbally encouraged to score using the entire range of the 10-point scale. Participants were then shown stimuli in the following sequence: still shots of all 43 models from the front, still shots of all 43 models from the side, still shots of

Table 2
Descriptive statistics of anthropometrics of female models

Measurement	*n*	Minimum	Maximum	Mean	S.D.
Abdominal depth (cm)	43	14.20	20.35	16.97	1.38
Acromial height (cm)[c]	41	122.35	143.65	130.85	4.79
Androgen equation	43	74.45	98.35	87.87	5.11
BMI (kg/m^2)[a]	42	17.76	24.90	21.94	1.74
Buttock height (cm)[d]	27	72.10	100.60	84.27	5.17
Chest circumference (cm)	43	76.50	95.90	85.63	5.00
Chest-to-underchest ratio	43	1.04	1.38	1.17	0.06
Estradiol (pg/ml)[b]	41	2.10	165.97	40.52	40.77
Hip circumference (cm)	43	81.90	104.30	93.38	4.95
Left 2nd to 4th digit ratio	43	0.93	1.04	0.99	0.03
Left digit 2 (cm)	43	5.88	7.89	6.92	0.38
Left digit 4 (cm)	43	6.02	8.12	7.01	0.44
Leg length (cm)	43	70.70	88.95	77.07	3.82
Leg-to-stature ratio	43	0.45	0.51	0.48	0.01
Mid-arm circumference (cm)	43	22.55	29.35	26.07	1.73
Pelvic width (cm)	43	21.75	32.45	26.53	1.96
Right 2nd to 4th digit ratio	43	0.92	1.03	0.98	0.03
Right digit 2 (cm)	43	6.03	7.92	6.89	0.42
Right digit 4 (cm)	43	5.92	8.15	7.02	0.43
Shoulder-to-leg ratio	43	1.03	1.83	1.67	0.13
Shoulder width (cm)	43	34.35	41.15	38.13	1.76
Sitting height (cm)	43	77.60	90.30	84.25	3.26
Stature (cm)	43	150.05	175.05	161.37	5.68
Underchest circumference (cm)	43	53.60	88.65	72.94	5.65
Waist circumference (cm)	43	58.10	77.50	69.13	4.54
Waist-to-hip ratio	43	0.63	0.82	0.74	0.04
Weight (kg)[a]	42	46.50	72.70	56.98	6.04

[a] Weight was not obtained from one model. Although we screened models for self-reported BMI ≥18, one model had a measured BMI <18.

[b] Estradiol was not measured in two models because of inadequate bloodspot samples.

[c] For two participants, recorded acromial height measurements were well outside the range for the rest of the sample and were therefore assumed to have been recorded erroneously.

[d] Buttock height was added as a measure only after data collection had been completed on 16 models.

Table 3
Correlations among selected anthropometric variables.

		Abdominal depth	Chest circumference	Waist circumference	Hip circumference	WHR	BMI	Chest to underchest
Abdominal depth	*r*	1	.599**	.792**	.563**	.388*	.770**	−0.160
	Significance (2-tailed)		.000	.000	.000	.010	.000	.307
	n	43	43	43	43	43	42	43
Chest circumference	*r*	.599**	1	.689**	.563**	0.260	.668**	0.282
	Significance (2-tailed)	.000		.000	.000	.092	.000	.067
	n	43	43	43	43	43	42	43
Waist circumference	*r*	.792**	.689**	1	.567**	.632**	.701**	−0.290
	Significance (2-tailed)	.000	.000		.000	.000	.000	.059
	n	43	43	43	43	43	42	43
Hip circumference	*r*	.563**	.563**	.567**	1	−0.278	.585**	0.002
	Significance (2-tailed)	.000	.000	.000		.071	.000	.991
	n	43	43	43	43	43	42	43
WHR	*r*	.388*	0.260	.632**	−0.278	1	0.270	−.357*
	Significance (2-tailed)	.010	.092	.000	.071		.084	.019
	n	43	43	43	43	43	42	43
BMI	*r*	.770**	.668**	.701**	.585**	0.270	1	0.001
	Significance (2-tailed)	.000	.000	.000	.000	.084		.993
	n	42	42	42	42	42	42	42
Chest to underchest	*r*	−0.160	0.282	−0.290	0.002	−.357*	0.001	1
	Significance (2-tailed)	.307	.067	.059	.991	.019	.993	
	n	43	43	43	43	43	42	43

* Correlation is significant at the .05 level (two-tailed).
** Correlation is significant at the .01 level (two-tailed).

all 43 models from the back and videos of two rotations of all 43 models. The still shots of the models were shown for 2 s, after which participants had 3 s to rate the models. Videos were 16 s long, consisting of two 8-s rotations. Again, participants were given 3 s to rate. Participants rated all four presentations of each model.

2.4. Analyses

Data were analyzed with two different approaches. In one approach, we calculated the average rating that each model received from all raters of a given sex from a given perspective. Four perspectives were included: video, front still shot, side still shot and back still shot. Bivariate correlations between these average ratings and each anthropometric variable were calculated. To explicitly compare our results with those of previous studies, multiple linear regression also was used to assess the independent effects of WHR and BMI.

Many of these anthropometric measures are correlated with each other and with attractiveness ratings. For example, WHR is correlated with waist circumference and abdominal depth and each of these is correlated with attractiveness (Table 3). To evaluate whether, for example, WHR has an effect on attractiveness ratings that is independent of the effect of these other variables, a multivariate model was constructed that considered all anthropometric variables for inclusion. Separate models were constructed for front, side, back and video ratings to evaluate whether particular anthropometric measures were more influential from a

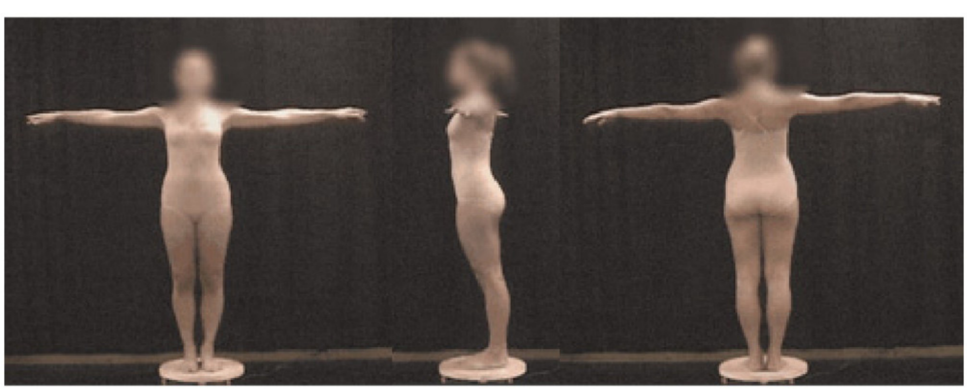

Fig. 1. Front, side and back views of one model. Her average attractiveness ratings from male raters were 5.4 (video), 5.2 (front), 6.5 (side), 5.4 (back). Her average attractiveness ratings from female raters were 6.7 (video), 5.5 (front), 6.5 (side), 6.5 (back). The average ratings for all 43 models from male raters were video=4.96, front=4.21, side=4.51, back=4.74. Overall average ratings from female raters were video=5.28, front=4.86, side=4.83, back=5.06.

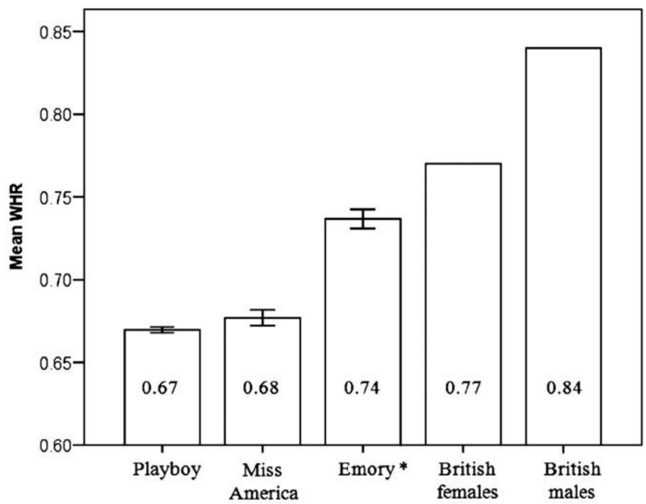

Fig. 2. Mean (±1 S.E.) ratio of waist-to-hip circumference for the present study (labeled with an *) in comparison with several other datasets.

given perspective. Regression models were constructed using stepwise forward variable selection, adding predictive variables until a significant improvement in the model performance was no longer achieved by adding variables. The statistical criterion for adding variables to the model was that the variable had a partial F-statistic with a p value of less than .01 when added to the model. Variables were no longer added when no such additional variable could meet this criterion. Since the significance of a variable can change depending upon the variables added afterwards, at each iteration of the variable selection process, variables were removed from the model if their p value exceeded .05. In addition to each of the anthropometric variables, judge sex and the interaction between judge sex and each variable were considered for inclusion.

In rare cases, a measurement was not obtained from a model or the measurement was not accurately recorded. In these cases, the missing or erroneous data (see Table 2) were replaced by the mean value of that variable for the rest of the sample. Erroneous data were limited to two measurements of acromial height.

3. Results

3.1. Anthropometrics of female models

Table 2 shows the mean, standard deviation and range of each anthropometric variable for the sample of 43 models. The mean WHR of our sample (0.74) is significantly higher than that previously reported for a sample of Playboy Centerfold Models (0.67) or Miss America Pageant winners (0.68) ($F_{624,2}$=70.88; p<.001) (Freese and Meland, 2002), but less than that observed in a sample of British females between the ages of 16 and 24 (Department of Health, 2007; Fig. 2). The higher ratio in the British sample is likely attributable to the fact that the British study did not restrict on BMI, whereas we restricted to women of healthy BMI (18–24).

3.2. Anthropometrics and attractiveness assessments of female models

3.2.1. Univariate analyses

Bivariate correlations between each anthropometric variable and the average attractiveness rating a model

Table 4
Anthropometric correlates of attractiveness, as rated by male and female judges, for all four stimulus types (video, front, side and back)

		Video		Front		Side		Back	
Measurement	*n*	Male	Female	Male	Female	Male	Female	Male	Female
Abdominal depth	43	−0.51**	−0.55**	−0.58**	−0.55**	−0.46**	−0.39**	−0.56**	−0.53**
BMI	42	−0.38*	−0.33*	−0.50**	−0.50**	−0.33*	−0.16	−0.46**	−0.42**
Chest circumference	43	−0.31*	−0.35*	−0.45**	−0.50**	−0.27	−0.12	−0.46**	−0.49**
Chest-to-underchest ratio	43	0.26	0.27	0.31*	0.23	0.31*	0.40*	0.14	0.2
Hip circumference	43	−0.19	−0.18	−0.34*	−0.32	−0.12	0.01	−0.33*	−0.29
Left digit 2	43	0.36	0.3	0.25	0.26	0.27	0.27	0.37*	0.27
Left digit 4	43	0.39	0.3	0.17	0.17	0.31*	0.3	0.32*	0.2
Leg length	43	0.35*	0.32*	0.28	0.34*	0.35*	0.38*	0.29	0.23
Leg-to-stature ratio	43	0.22	0.31*	0.32*	0.39*	0.21	0.26	0.27	0.25
Mid-arm circumference	43	−0.36*	−0.33*	−0.42**	−0.40**	−0.37*	−0.22	−0.37*	−0.32*
Pelvic width	43	−0.08	−0.16	−0.35*	−0.30*	0.02	−0.01	−0.18	−0.17
Right digit 2	43	0.37*	0.31*	0.21	0.25	0.34*	0.36*	0.32*	0.21
Right digit 4	43	0.42**	0.32*	0.22	0.24	0.32*	0.33*	0.37*	0.25
Stature	43	0.32*	0.2	0.14	0.17	0.32*	0.32*	0.2	0.12
Underchest circumference	43	−0.13	−0.16	−0.31*	−0.31*	−0.17	−0.12	−0.22	−0.27
Waist circumference	43	−0.48**	−0.49**	−0.61**	−0.59**	−0.51**	−0.40**	−0.49**	−0.53**
WHR	43	−0.37*	−0.39**	−0.39*	−0.39*	−0.47**	−0.47**	−0.26	−0.34*

Correlation coefficients between anthropometric variables and attractiveness ratings are listed. Only variables that were significantly correlated with at least one of the eight ratings are included.

* p<.05.

** p<.01.

received are presented in Table 4. Table 4 demonstrates remarkably similar correlations for male and female raters, suggesting that male and female raters use similar anthropometric characteristics to evaluate attractiveness. Additionally, male and female raters agree on the relative ranking of models, as evidenced by strong positive correlations between male and female ratings of model videos (r=0.93, p<.001), as well as front (r=0.94, p<.001), side (r=0.93, p<.001) and back (r=0.92, p<.001) still shots. Similar agreement between male and female raters has been noted previously (Fan et al., 2004; Tovee et al., 2002). Variables showing particularly strong and consistent negative correlations with attractiveness across sex and view type include abdominal depth (Fig. 3), mid-arm circumference, chest circumference, waist circumference, WHR and BMI. Leg length was the only variable showing a strong and consistent positive correlation with attractiveness across view types for both sexes.

Previous studies have investigated the relative contribution of BMI and WHR to attractiveness assessments (Fan et al., 2004; Tovee et al., 2002). Scatterplots of BMI and WHR against male attractiveness ratings of front picture stimuli are shown in Fig. 4A and B. BMI and WHR are not significantly correlated (r=0.27, p>.05), but each is negatively correlated with attractiveness scores (r=−0.50 for BMI and r=−0.39 for WHR). These correlations are not improved when anthropometric variables are squared to allow for the previously reported nonlinear relationships with attractiveness (Fan et al., 2004; Tovee et al., 1999). To assess the independent contribution of the two variables to attractiveness ratings, both were entered as independent variables in a multiple linear regression model. For male ratings of front picture stimuli, BMI explained 19% (partial r=−0.44, p<.01) and WHR explained 9% variance (partial r=−0.28, p=.05). For male video ratings, quadratic terms explained slightly more variance than linear terms. BMI^2 explained 11% (partial r=−0.33, p=.05) and WHR^2 explained 8% (partial r=−0.28, p=.08) of variance.

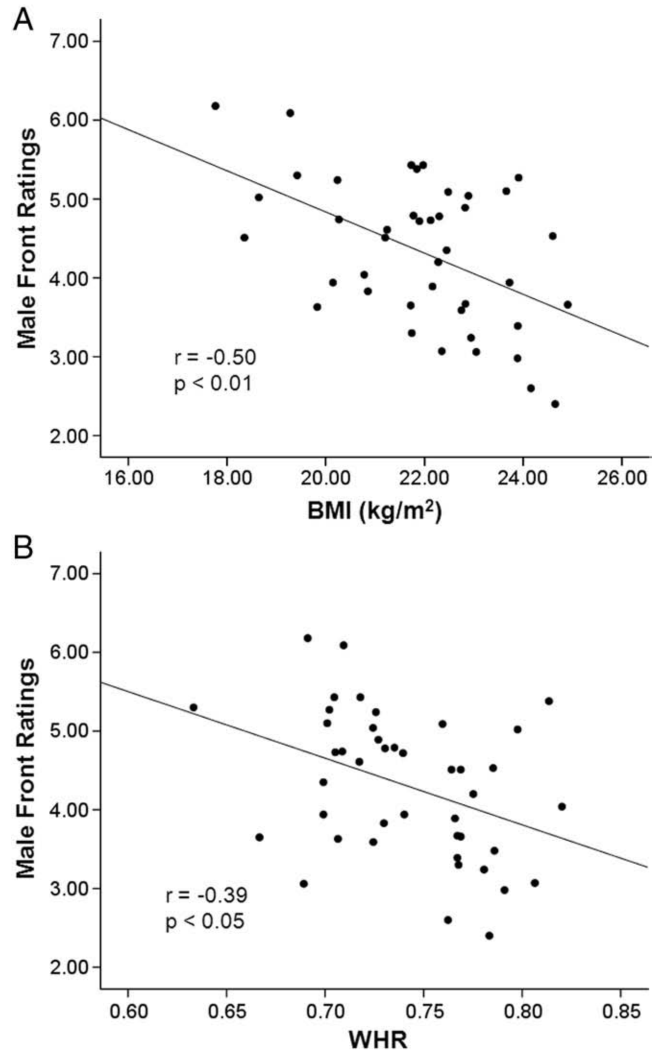

Fig. 4. Relationship between BMI, WHR and attractiveness ratings for front-view 2D picture stimuli. (A) Front-view ratings vs. BMI, (B) front-view ratings vs. WHR.

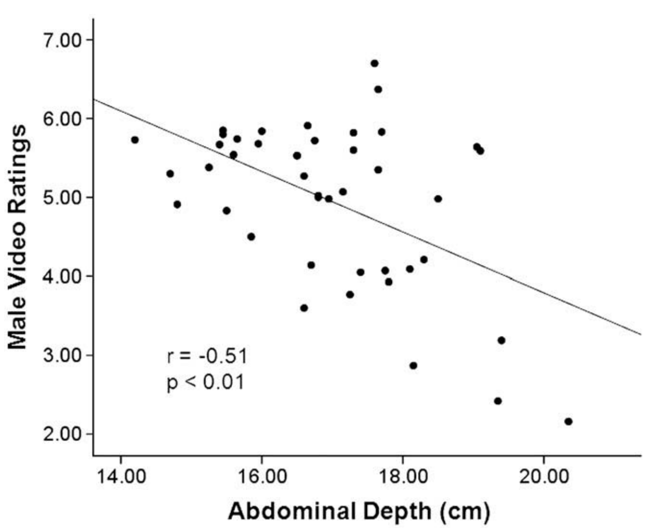

Fig. 3. Correlation between abdominal depth and average male ratings for video stimuli.

3.2.2. Multivariate analyses

The multivariate model for video ratings included only two significant anthropometric predictors: abdominal depth and acromial height. Abdominal depth was a strong negative predictor of attractiveness ratings, and acromial height was a positive predictor. For front-view ratings, waist circumference was a very strong negative predictor, whereas leg length and androgen equation were positive predictors. Sex was also a significant predictor, with female judges rating models on average 0.56 points higher than male judges. For side-view ratings, waist circumference was again a strong negative predictor. Mid-arm circumference was also a negative predictor, and both leg length and body weight were positive predictors. Finally, for back-view stimuli, chest circumference was a negative predictor, whereas leg length, chest-to-underchest ratio and length of the fourth digit on the right hand were positive predictors (Table 5).

3.3. Estradiol, anthropometrics and attractiveness

There were no significant correlations between estradiol levels and any of the attractiveness measures or anthropometric variables. However, we conducted a separate analysis for the subgroup of 20 non–oral contraceptive users in our sample to evaluate the possibility that effects were only present for naturally cycling women. In this subgroup, there were no significant correlations between estradiol levels and any of the attractiveness measures (video, front, side, back), and there was only one significant correlation between estradiol and the anthropometric variables. Hip circumference was positively correlated with estradiol levels (r=0.46, p<.05).

3.4. Second to fourth digit ratio, anthropometrics and attractiveness

Second to fourth digit ratio was included as a presumed marker of prenatal androgen exposure (Lutchmaya et al., 2004). Neither the right nor the left second to fourth digit ratio was correlated with any measure of attractiveness. The lone correlation between digit ratio and anthropometrics was a weak negative correlation between left digit ratio and chest circumference (r=−0.32, p>.05).

Table 5
Significant anthropometric predictors of attractiveness ratings in multiple linear regression models for each of the four view types

View	Variable	Estimate	S.E.	F Value	p value
Back	Intercept	4.90	0.08	3486.13	2.38E-68
Back	Chest circumference	−0.14	0.02	64.11	7.28E-12
Back	Chest/underchest ratio	6.76	1.48	20.83	1.77E-05
Back	Leg length	0.07	0.03	6.97	9.96E-03
Back	Right digit 4 length	0.68	0.23	8.73	4.09E-03
Model R^2=0.52					
Front	Intercept	4.31	0.10	2053.13	2.60E-59
Front	Sex	0.56	0.13	17.08	8.68E-05
Front	Androgen equation	0.04	0.02	7.77	6.61E-03
Front	Leg length	0.10	0.02	21.70	1.23E-05
Front	Waist circumference	−0.16	0.02	102.97	4.36E-16
Model R^2=0.64					
Side	Intercept	4.67	0.08	3487.16	2.35E-68
Side	Leg length	0.06	0.03	4.15	4.49E-02
Side	Mid-arm circumference	−0.20	0.07	7.65	7.02E-03
Side	Waist circumference	−0.17	0.03	44.35	3.04E-09
Side	Weight	0.11	0.03	15.90	1.45E-04
Model R^2=0.52					
Video	Intercept	5.12	0.09	3222.83	3.45E-68
Video	Abdominal depth	−0.46	0.07	47.24	1.08E-09
Video	Acromial height	0.09	0.02	21.28	1.43E-05
Model R^2=0.42					

R^2=proportion of variance explained by model.

4. Discussion

4.1. Anthropometric predictors of female attractiveness

There are theoretical grounds for predicting a relationship between low WHR and attractiveness, given that a low WHR is associated with good health and reproductive prospects (Lassek & Gaulin, 2008; Singh, 2002). This prediction is supported by substantial evidence from a wide range of societies (Singh, 2002), with the important exception of two traditional, non-Western societies (discussed below) (Wetsman & Marlowe, 1999; Yu & Shepard, 1998). Despite this association, other evidence suggests that BMI is a stronger predictor of attractiveness than WHR, even among women of healthy weight, and it has been argued that BMI is indeed the primary determinant of female body attractiveness (Tovee et al., 2002, 1999). For a sample of women with a restricted BMI range of 18–26, Tovee et al. (2002) used multiple linear regression to show that BMI and WHR respectively explained 27% and 5% of variance in attractiveness ratings for front-view picture stimuli. In a similar analysis of front-view picture stimuli, we find that BMI and WHR explain 19% and 9% variance, respectively. Thus, we also find BMI to be a stronger predictor, but the discrepancy is not as large as that reported by Tovee et al. (2002). The difference could relate to different preferences between UK and US undergraduate judges.

Despite these findings that are broadly consistent with earlier studies, when we consider other anthropometric variables that have not been previously investigated, it becomes clear that BMI is not the primary determinant of attractiveness in our sample. In univariate analyses, both abdominal depth and waist circumference explain more variance in attractiveness ratings than does BMI, across all four view types. Moreover, BMI is not a significant predictor in any of our multivariate analysis, after controlling for the other variables in the model. This suggests that the relationship between BMI and attractiveness can be explained by BMI's association with another anthropometric variable in the multivariate model that is correlated with attractiveness. Nevertheless, as evident in Table 3, many of these variables are highly correlated with one another and they could all be tapping a single underlying construct such as healthy fat distribution or estradiol level. However, the absence of correlations between most of these variables and estradiol argues against the latter possibility (but see Section 4.5). This idea could be further explored in a larger sample of subjects using factor analysis.

For video stimuli, the strongest negative predictor in the multivariate model is abdominal depth. Abdominal depth is the distance from the umbilicus to the small of the lower back and is therefore one dimension of waist circumference. However, abdominal depth cannot be perceived from the front-view stimuli that typically have been used in earlier studies (Fan et al., 2004; Marlowe et al., 2005; Thornhill & Grammer, 1999). Similarly, abdominal depth is not a significant predictor in our regression model for ratings of front-view stimuli. Thus, future studies of attractiveness of human female bodies would benefit from inclusion of a 3D view in which abdominal depth can be perceived. Small abdominal depth reflects the absence of pregnancy and reduced probability of intestinal parasites (Singh, 2002). Additionally, abdominal fat appears to decrease the availability of essential fatty acids needed for fetal and infant brain development (Lassek & Gaulin, 2008). Finally, stress hormones promote abdominal fat deposition (Lamounier-Zepter et al., 2006), so small abdominal depth might also signal the ability to cope with chronic stress and avoid its known deleterious effects on reproduction (Sapolsky, 1994).

Waist circumference was a strong negative predictor of attractiveness for both front- and side-view stimuli. Abdominal depth is one component of waist circumference and the two are very highly correlated in our dataset (r=0.79, p<.001). The fact that estrogen replacement therapy in postmenopausal women is associated with decreased waist circumference (Mayes & Watson, 2004) raises the possibility that small waist circumference is associated with high estrogen levels and consequent increased fertility. However, we did not detect a significant correlation between estrogen and either waist circumference (r=0.18, p>.05) or abdominal depth (r=0.38, p>.05) in our sample. Nevertheless, like abdominal depth, small waist circumference reflects the absence of pregnancy, reduced probability of intestinal parasites and increased availability of essential fatty acids needed for fetal and infant brain development. Thus, the preference for small abdominal depth and waist circumference is an adaptive one, potentially shaped by natural selection. This hypothesis is supported by recent evidence that ancient literature from different cultures around the world all describes a narrow waist as a beautiful characteristic (Singh et al., 2007), suggesting that this may be a cross-culturally consistent preference, at least in environments where the food is not scarce.

The most consistent positive predictor of attractiveness was leg length, which was significant for front-, side- and back-view stimuli. A relationship between leg length and attractiveness has been reported previously (Fan et al., 2004; Sorokowski & Pawlowski, 2008). Although the origin of this preference is uncertain, relative leg length has increased throughout human evolution, and one possibility is that long legs became attractive because they enabled more efficient locomotion that improved foraging efficiency in our hominid ancestors as they hunted and gathered on the African savannah (Isbell et al., 1998; Pontzer, 2007). Leg growth is particularly sensitive to environmental influence during the prepubertal period. Short legs may therefore signal an inability to expend energy on leg growth during development whilst coping with adverse environmental factors such as nutritional or energetic deficiency (Sorokowski & Pawlowski, 2008). Finally, given that a substantial amount of fat is deposited in the subcutaneous tissue of the legs, a preference for longer legs could also be related to a preference for women with more lower-body fat in general.

Other variables were inconsistently associated with attractiveness across the different view types. Acromial height was a positive predictor for video stimuli, but not for any of the other views. Acromial height is highly correlated with stature. This finding is somewhat counterintuitive, given that previous studies have not found tallness to be associated with attractiveness of women (Kurzban & Weeden, 2005; Shepperd & Strathman, 1989). Nevertheless, Playboy models and Miss America pageant winners are on average more than 2 in. taller than young women in general (Byrd-Bredbenner & Murray, 2003).

For front-view stimuli, the androgen equation was a positive predictor of attractiveness. This was a counter-intuitive result, as higher ratios are typically associated with masculinity (Tanner, 1990). Shoulder width is primarily affected by androgen and estrogen exposure at puberty, prior to fusion of the epiphyseal growth plates. One possible interpretation of this finding is suggested by the observation that early-maturing, healthy populations such as US populations have very high levels of the adrenal androgen DHEAS for their age and pubertal stage (Worthman, 1999). High levels of DHEAS should broaden shoulders. Thus, broad shoulders could signal health and good nutrition during pubertal development.

For side-view stimuli, mid-arm circumference was a negative predictor of attractiveness. In most cases, large mid-arm circumference is indicative of fat accumulation in the arms. Weight was actually a positive predictor for side-view stimuli. However, given that waist circumference and mid-arm circumference are negative predictors, this would have to be weight that is not concentrated in the abdominal region or in the arms. One possibility is that the "attractive" weight is concentrated in gluteofemoral fat, which has been linked with cognitive and neurodevelopment of infants (Lassek & Gaulin, 2006).

For back-view stimuli, chest circumference was a negative predictor. Chest circumference is affected by breast size, but also by trunk breadth and thickness, which can include fat deposits on the back. Chest-to-underchest ratio was a positive predictor of attractiveness for back-view stimuli. This was unexpected given that breast size cannot be viewed from the back-view stimuli. However, chest-to-underchest ratio may be correlated with the ratio of the width of the upper to mid back region, and this may be what raters find attractive, though this would require further investigation. Finally, the length of the fourth digit on the right hand was a positive predictor of attractiveness in this view. We consider it unlikely that raters are specifically attending to this trait, but rather something correlated with it that we have not measured, and that is perhaps related to prenatal androgen exposure.

4.2. Comparison of male and female ratings

Our study design afforded the opportunity to compare men's preferences with women's estimates of their preferences. Only for front-view stimuli was there a significant difference in ratings given by male and female judges, with males rating an average of 0.56 points lower than females. Despite this, both the relative ranking of models, as well as the anthropometric predictors of attractiveness, showed a remarkable degree of similarity between male and female judges. There were no sex-by-anthropometry interactions in any of the multivariate models. This implies that female judges are able to very accurately assess the preferences of their male peers, an ability that may also be adaptive.

4.3. Sample distribution of attractiveness

The average rating for all of our models was 4.9, on a scale from 1 to 10. However, the distribution is highly skewed such that the upper end of the rating scale is underrepresented. Indeed, only two models received an average rating that was higher than 6. These results were obtained despite the fact that participants were shown a range of sample stimuli prior to beginning the rating procedure and were specifically instructed to use the entire rating scale from 1 to 10. Two other studies have similarly reported a lack of high attractiveness ratings for their stimuli (Fan et al., 2004; Tovee et al., 2002). One possible explanation is that women are perceived as less attractive when devoid of flattering clothing and accessories as in our study. Moreover, given the importance of facial characteristics, the absence of facial stimuli may reduce raters' willingness to confer maximal ratings regardless of instructions to focus on the body alone. Another possibility is that despite instructions to the contrary, participants' assessments of attractiveness are influenced by frequent exposure to unusually attractive images of the female body presented in the media. For example, the strongest negative predictor of attractiveness in our study, waist circumference, is several centimeters larger in our sample (69.1 cm) compared with Miss America pageant winners (60.8 cm) or Playboy centerfold models (59.1 cm). A final possibility is that our modern lifestyle, often characterized by overeating and limited physical activity, results in bodies that are not as well conditioned and, consequently, not as aesthetically pleasing as those of our ancestors throughout most of human evolution. This last hypothesis could be tested by conducting a study similar to this one among foraging societies characterized by high levels of physical activity and more restricted food intake. Regardless of the reason for the skewed ratings, the paucity of highly attractive stimuli means that these studies tell us more about the variables that distinguish moderately attractive from unattractive body types, rather than highly attractive body types.

4.4. Hormones, anthropometrics and attractiveness

In a sample on 119 noncontracepting Polish women, Jasienska et al. (2004) showed that salivary estradiol levels were positively correlated with breast size and negatively correlated with WHR. The magnitude of these correlations was, however, not large (between r=0.2 and r=0.3), suggesting that we may not have sufficient power to detect these effects in our sample of 20 naturally cycling women. Moreover, in contrast to the Jasienska et al. study, we did not hold constant the cycle stage when estradiol was collected from each woman. This adds noise to the data, making it more difficult to detect an effect. Therefore, it is not surprising that we failed to replicate the correlations reported by Jasienska et al. However, we did observe a significant positive association between estradiol and hip circumference (r=0.46, p<.05), which is of course one component of WHR. This is consistent with evidence for increased fat deposition in hips and thighs in girls when estradiol levels increase at puberty (Lassek & Gaulin, 2007). However, this is to our knowledge the first report of a direct association between estradiol levels and hip circumference in adult women.

If estradiol is linked to fertility, one might predict that male judgments of female attractiveness would correlate with estradiol levels. However, there were no significant correlations between estradiol levels and any of our attractiveness measures (video, front, side, back). Again, this could be attributable to our limited sample size or the fact that we did not control for cycle stage.

4.5. Origin of preferences

On its own, our study cannot establish whether the observed preferences result from innate predispositions shaped by natural selection, responses to local ecological environments, or cultural diffusion and exposure to Western media. The evolutionary hypothesis is reasonable, given the known health and reproductive correlates of abdominal fat (Lassek & Gaulin, 2008; Singh, 2002). Studies of populations with limited exposure to the West provide important test cases of this hypothesis. Although some of these groups express a preference for lower WHRs (Singh, 2002; Sugiyama, 2004), and presumably less abdominal fat, at least one such group reportedly expresses the opposite preference (Yu & Shepard, 1998). However, as with other studies, the stimulus set used in this study confounds BMI with WHR so that it is not possible to dissociate a preference for high WHR from a preference for high BMI (and the latter may be adaptive in environments where food is limited). Moreover, this study, like most other studies of remote hunter-gatherer populations, utilized line drawings of European-looking females, which raises questions about its ecological validity. Thus, the cross-cultural consistency of the preference for low levels of abdominal fat remains an unresolved issue.

5. Conclusion

Our results show that abdominal depth and waist circumference are the strongest predictors of attractiveness of female bodies, stronger than either BMI or WHR. Women with small abdominal depth and waist circumference are more likely to be healthy and nonpregnant, suggesting that this may be an adaptive preference shaped by natural selection. Leg length was a consistent positive predictor of attractiveness, perhaps because it reflects biomechanical efficacy or healthy prepubertal growth, unhindered by nutritional or energetic deficiency. We also find that female judges are able to very accurately gauge the preferences of their male peers. Our results show that conclusions regarding anthropometric predictors of attractiveness are influenced by the visual perspective of the rater, as well as the anthropometric variables considered for analysis.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.evolhumbehav.2008.08.007.

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