THE ROYAL SOCIETY

Visual cues to female physical attractiveness

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Evolutionary psychology suggests that a woman's sexual attractiveness is based on cues of health and reproductive potential. In recent years, research has focused on the ratio of the width of the waist to the width of the hips (the waist-to-hip ratio (WHR)). A low WHR (i.e. a curvaceous body) is believed to correspond to the optimal fat distribution for high fertility, and so this shape should be highly attractive. In this paper we present evidence that weight scaled for height (the body mass index (BMI)) is the primary determinant of sexual attractiveness rather than WHR. BMI is also strongly linked to health and reproductive potential. Furthermore, we show how covariation of apparent BMI and WHR in previous studies led to the overestimation of the importance of WHR in the perception of female attractiveness. Finally, we show how visual cues, such as the perimeter–area ratio (PAR), can provide an accurate and reliable index of an individual's BMI and could be used by an observer to differentiate between potential partners.

Keywords: body mass index; female beauty; mate selection; sexual attractiveness; waist-to-hip ratio

1. INTRODUCTION

Evolutionary psychology is natural selection applied to human behaviour (Thornhill & Gangestad 1996). Selection will favour those patterns of behaviour that can solve the basic environmental problems that face an individual. One of the most fundamental of these problems is mate selection: how do we choose a partner? It is important that we are sensitive to the physical cues that honestly signal that one individual is more desirable (i.e. fitter and with a better reproductive potential) than another, and use them to choose the partner which is most likely to enhance our chances of successful reproduction. The wrong choice will obviously have a negative impact on an individual's potential for reproduction, so one might expect very strong selective pressures for the development of mechanisms that accurately detect cues to health and fertility in potential partners.

In women, two potentially critical cues are shape and weight. As far as shape is concerned, research has focused on the ratio of the width of the waist to the width of the hips (the waist-to-hip ratio (WHR)). A low WHR (i.e. a curvaceous body) is believed to correspond to the optimal fat distribution for high fertility (Zaadstra *et al.* 1993), and so this shape should be highly attractive (Singh 1993*a*,*b*). This has been tested by asking subjects to rate line drawings of women for attractiveness (Singh 1993*a*,*b*, 1994*a*,*b*, 1995; Henss 1995; Furnham *et al.* 1997). The images are in three series: thin, normal and fat. Within each series, the WHR of the figures is varied. The studies suggest that the optimal WHR for attractiveness is 0.7 (Singh 1993*a*,*b*, 1994*a*,*b*, 1995; Henss 1995; Furnham *et al.* 1997) and that WHR is a more important predictor of attractiveness than the apparent weight of the female figure (Singh 1994*a*).

Recently, we reported that weight scaled for height (i.e. the body mass index (BMI), the units of which are $kg\,m^{-2}$) may be a far more important factor than WHR in determining the attractiveness of a female body (Tovée *et al.* 1998*a*). This result is consistent with another study that showed that successful female fashion and glamour models all fall within a narrow BMI range (Tovée *et al.* 1997). It is well established that changes in BMI also have a strong impact on health (Manson *et al.* 1995; Willet *et al.* 1995) and reproductive potential (Reid & Van Vugt 1987; Frisch 1988; Lake *et al.* 1997). So a mate choice strategy based on BMI would also favour reproductive success.

Here we address three questions central to this debate. First, we investigate the relative importance of BMI and WHR in the perception of female attractiveness. Second, if BMI plays a role in the perception of attractiveness, what visual cues can be used to give an accurate and reliable measure of an individual's BMI? Third, if BMI is the principal cue to physical attractiveness rather than WHR, why do our results differ from those of previous studies (see, for example, Singh 1993*b*; Henss 1995; Furnham *et al.* 1997)?

2. METHODS

We asked 40 male undergraduate subjects (mean age: 20 years, 8 months; s.d. 1 year, 4 months) to rate colour images of 50 real women in front view, illustrated in figure 1. Note that figure 1 is intended only as a representative collage of our stimuli; in the actual experiment, subjects saw only one image at a time.

To generate the images, consenting women were videoed standing in a set pose at a standard distance, wearing tight grey leotards and leggings. Images were then frame-grabbed and stored as 24-bit colour pictures. The use of high-resolution, colour photographic images is a more realistic than the line drawings used to date (see, for example, Singh 1993*a*,*b*, 1994*a*,*b*, 1995; Henss 1995; Furnham *et al.* 1997; Tassinary & Hansen 1998). However, it should be borne in mind that a two-dimensional (2D) image is unlikely to capture all the visual cues available from a three-dimensional (3D) image seen from the same viewing point.

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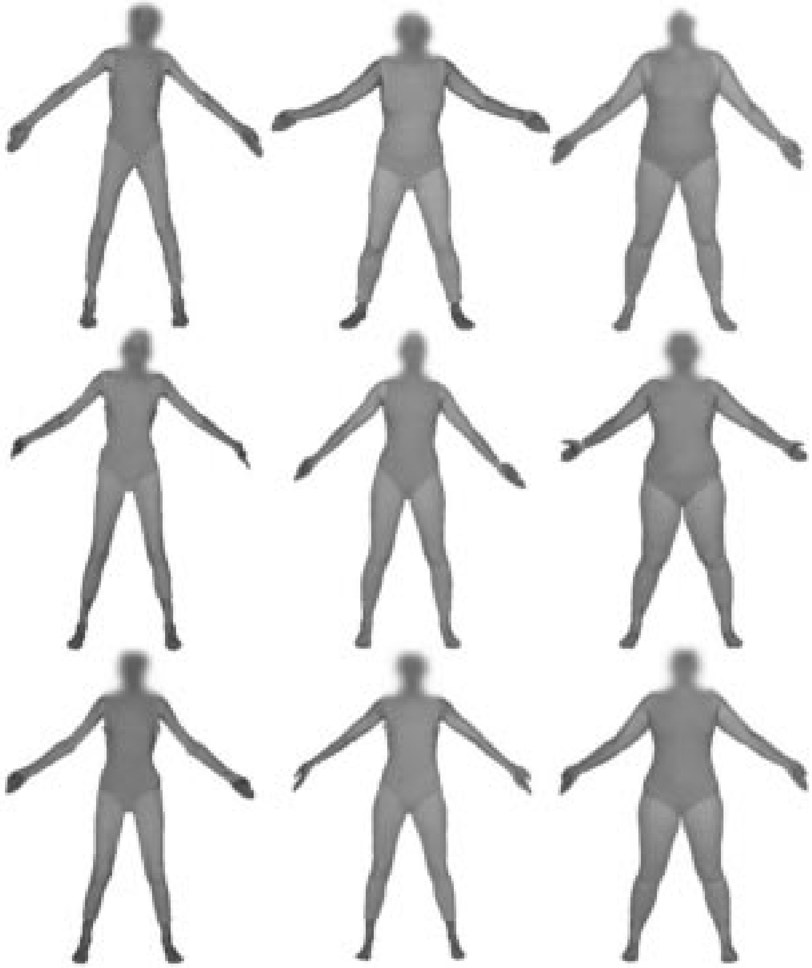

Figure 1. A 3×3 matrix illustrating some of the images used in the study. Down each column of the matrix, BMI is approximately constant while WHR reduces (range 0.7–0.83). Along each row of the matrix, WHR is approximately constant while BMI increases (range 13–29).

For our stimulus set, we drew ten images of women from each of five BMI categories (Bray 1978): emaciated (below 15), underweight (15–19), normal (20–24), overweight (25–30) and obese (above 30). Note that 'normal' here refers to a 'normal healthy range' of BMI and not frequency of occurrence in the population; recent epidemiological surveys have claimed that only a minority of people fall into this category (see Winkelgren 1998). The women in our study varied in WHR from 0.68–0.98. The range of WHR and BMI represented in our images corresponds closely to the range of values found in a survey of 2756 Finnish women (Marti *et al.* 1991). We obscured the heads of the women in our images, so that they could not be identified and facial attractiveness would not be a factor in subjects' ratings.

Subjects were encouraged to use the whole range of attractiveness ratings from 0 (least attractive) to 9 (most attractive). The 50 images were randomized, and subjects were presented the entire set twice. The first run through was used to make subjects aware of the range of variability of body features represented in the images. Only on the second run through were subjects asked to rate them.

3. RESULTS

(a) *BMI versus WHR*

Figure 2*a*,*b* shows plots of attractiveness rating as a function of BMI and WHR, respectively. It is clear from figure 2*a* that the relation between BMI and attractiveness is nonlinear; small increases or decreases in BMI either side of the range 18–19 radically reduce attractiveness ratings. Figure 2*b* illustrates a weak negative correlation of attractiveness with WHR; attractiveness rating decreases as values of WHR reflect an increasingly tubular body shape.

There are a large number of nonlinear functions that could, in principle, be used to model these data. Because our analysis was post hoc and exploratory, we chose the simplest approach possible, which was to include second- and third-order terms in a multiple regression model (see Altman 1991). There appears to be little justification in the psychological literature for fitting a more complex function. The model we used was

$$\text{model: } y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + e,$$

where y, attractiveness rating; a, intercept; e, random error; x_1, age of woman in image; x_2, WHR; x_3, BMI; x_4, BMI^2; and x_5, BMI^3.

We explored a variety of different methods for rejecting or retaining explanatory variables, including fitting of the complete model, backward elimination, forward selection and stepwise selection. The total variance explained by these different methods varied between 75% and 76.4%. Because there was little to choose between them, we

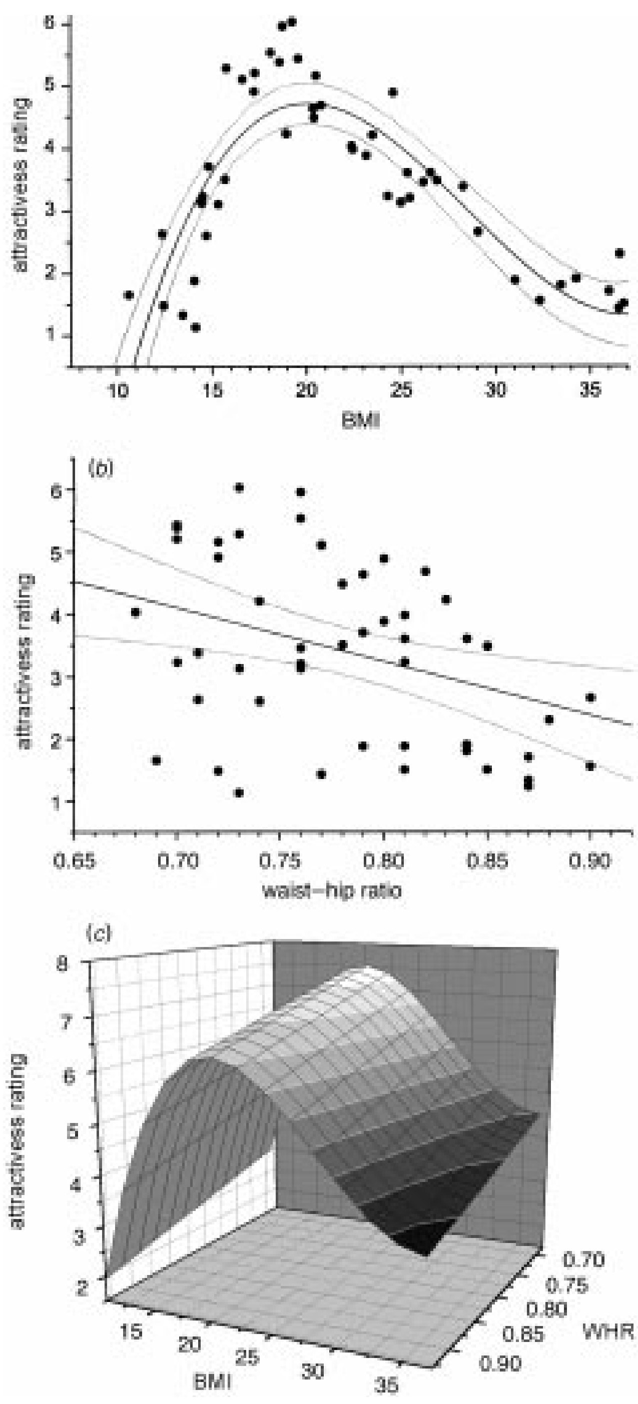

Figure 2. (*a*,*b*) Plots of attractiveness as a function of BMI and WHR, respectively. Each point represents the average of the 40 attractiveness judgements made by the male subjects. Regression lines (solid lines) and their 99% confidence limits (dotted lines) are superimposed. (*c*) A 3D surface plot illustrating the best-fit model. It illustrates that the largest possible change in attractiveness ratings due to BMI is 5.8 times bigger than that for WHR.

report the simplest model in full: $y = 4.65 - 0.016x_1 - 3.59x_2 + 0.025x_3 - 0.035x_4 + 0.0014x_5$. The analysis showed that, although attractiveness ratings were both significantly ($p < 0.05$) explained by BMI and WHR, the effect sizes are dramatically different: BMI accounted for 73.7% of the variance, whereas WHR accounted for only 2.3%. Figure 2*c* is a 3D surface plot that illustrates the best-fit model.

The above analysis used a wide range of BMI and WHR values. It might be argued that extreme values of BMI and WHR are comparatively rare, and that such 'outliers' could bias the results unduly. Therefore we ran a second analysis in which we restricted the range of images to be included. Figure 3*a*,*b* shows histograms for BMI and WHR measured in 467 women from the Newcastle-upon-Tyne area, i.e. the same population from which we gathered our images. The ages of the women in this sample ranged between 19 and 46 years. Values for BMI have been logged to moderate the influence of the skew that we found in the original distribution and which is clearly visible in the inset graph (skewness = 1.48). Gaussian curves have been fitted to the two distributions on the basis of their sample means and standard deviations.

In our second analysis, we used the distributions illustrated in figure 3 to limit the range of BMI represented in the images, while leaving WHR unrestricted. This strategy provided a particularly stringent test of our data, because it acts to favour any effect of WHR. According to figure 3, the range of $\log_{10}$ BMI that represents ± 1 s.d. from the sample mean is 1.25–1.42 (i.e. actual BMI values of 17.99–25.76). By applying this criterion, we were left with data from the judgements made about 19 out of the original 50 images. Note that if we had not used the logged distribution in figure 3, the range of BMI representing ± 1 s.d. from the mean would have been greater, i.e. 14.8–30.67. The range of WHRs represented in these 19 images is 0.68–0.83. It represents 1.8 s.d. below and 1.4 s.d. above the sample mean for WHR shown in figure 3. Thus, the variability of WHR in this analysis is considerably greater than that for BMI.

Inspection of figure 2*a* shows that attractiveness ratings are linearly related to BMI over the range 18–26. Therefore, we ran a linear multiple regression analysis to assess the relative contributions that BMI and WHR made in explaining attractiveness ratings, while controlling for any confounding influence of the age of the women in the images. The model we used was

$$\text{model: } y = a + b_1x_1 + b_2x_2 + b_3x_3 + e,$$

where y, attractiveness rating; a, intercept; e, random error; x_1, age of woman in image; x_2, WHR; x_3, BMI.

The correlation between BMI and WHR in the 19 images was weak ($r = 0.22$) and non-significant ($p = 0.33$). In view of this poor correlation, and the fact that there were only 19 images on which to estimate the main effects, we did not estimate interaction terms, as they would be too unreliable. The same line of reasoning also explains why we did not try to estimate interaction terms in the main analysis of all 50 images. The model above accounted for 71% of the variance in attractiveness ratings, and demonstrated significant effects only for BMI ($F_{1,15} = 24.5$, $p < 0.0005$). Thus we argue that, even when WHR is given an unfair advantage with respect to BMI, the latter is much better in accounting for the way in which males judge the attractiveness of female body shape.

(b) *Visual cues to BMI*

BMI is a normalized weight measure. In comparison, WHR is an inherently visual cue. If BMI is to be a

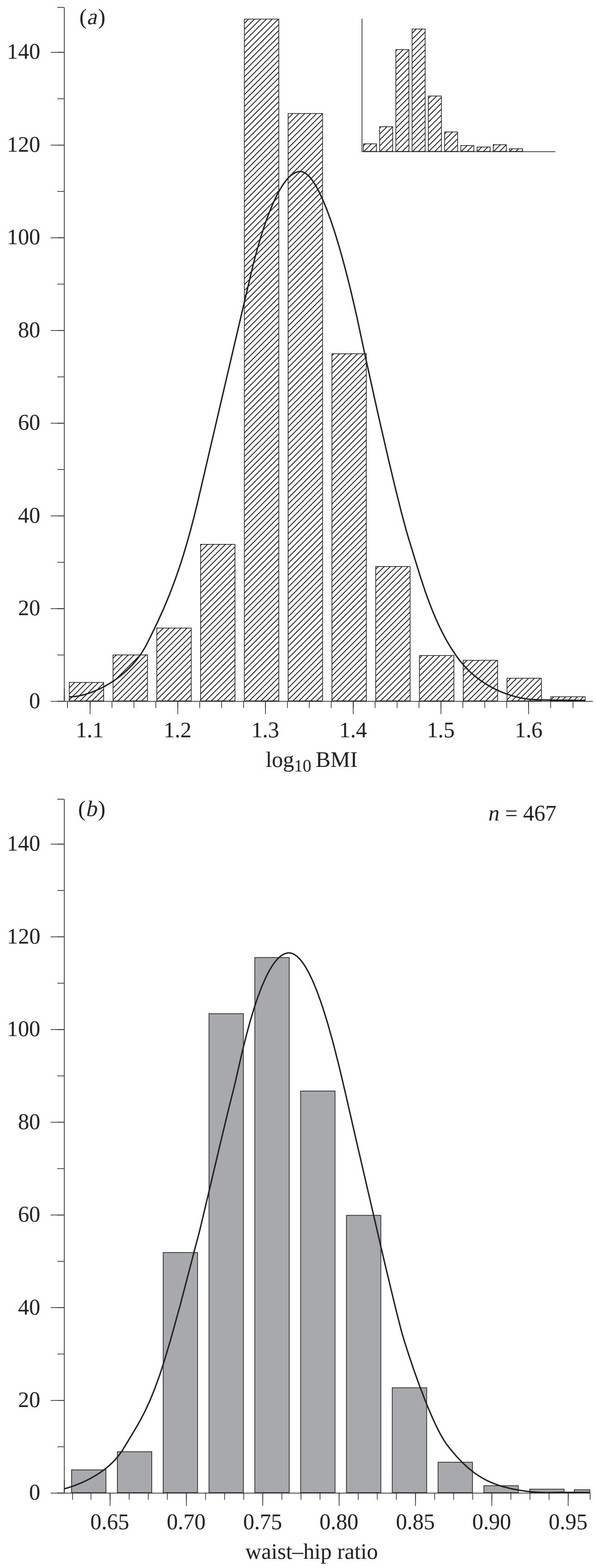

Figure 3. (*a*,*b*) Histograms for BMI and WHR measured in 467 women. Values for BMI have been logged in order to moderate the influence of the skew in the original distribution shown in the inset. Gaussian curves have been fitted to the distributions on the basis of their sample means and standard deviations.

plausible factor in the attractiveness of women, then it ought to have a visual correlate; the eye does not have a set of bathroom scales and a tape measure. In our 2D images, the potential visual cues to BMI are limited. Considering the images at their most basic, they are little more than silhouettes of bodies in front view. Can we derive an accurate measure of BMI from so little information? The answer is yes. If we take the path length around the perimeter of a figure and divide it by the area within the perimeter (the perimeter–area ratio (PAR)), we find that this ratio correlates very well with BMI. Figure 4*a* is a plot of PAR against BMI for the 50 images we used in our study. The Pearson correlation coefficient for this relationship is $r = 0.97$ ($p < 0.0001$). Thus PAR provides an accurate and reliable visual proxy of BMI.

In addition, there are other slightly less reliable, but simpler, cues to BMI. As we are all too aware, as we put on weight we tend to expand in width. Could just a change in body width accurately signal BMI? To answer this question we frame-grabbed images of 134 women across all five categories of the BMI range. For each image, we measured the width of 11 horizontal slices across the upper body. It was critical to ensure that, across all subjects, the relative position of each slice on the torso was comparable. To do this we positioned the first slice across the acromioclavicular joints and the 11th slice across the top of the legs level with the perineum. We then divided the vertical distance between these upper and lower limits by ten and positioned the remaining slices accordingly. This procedure is illustrated in figure 4*b*. Finally, we measured the 11 slice widths from each image and scaled them to recover the real-life dimensions of the participant's body.

Figure 4*c* is a 3D surface plot illustrating the change in shape across these slices with change in BMI. A convenient way to interpret figure 4*c* is to imagine a person lying on her right side, facing towards the reader. In this position, for example, variation in the distance across the shoulders as a function of body weight is represented by slice 2. As might be expected, figure 4*c* shows that this distance changes relatively little with increasing body weight. However, figure 4*c* does capture the fact that if women increase their body weight, the effect on body shape tends to be localized. Specifically, fat is deposited around the chest, waist and hip–thigh regions. To determine how well correlated these increases are with BMI we ran Pearson's correlations. The *r* values are plotted in figure 4*d*. As can be seen, the width of these latter slices are a reasonably good guide to BMI in real bodies. The waist is the most reliable guide to BMI. This may be because changes in the width of the chest and hips are constrained by the underlying bone structure, whereas the waist has more freedom of movement to reflect a change in BMI.

(c) *The covariation problem*

The results of our experiment suggest that BMI is a much stronger cue for physical attractiveness than WHR as has previously been suggested (Singh 1993*a*,*b*, 1994*a*,*b*). Moreover, the fact that there exist several visual correlates of BMI means that BMI is a cue that could be used in real life and not just in the laboratory. Why are

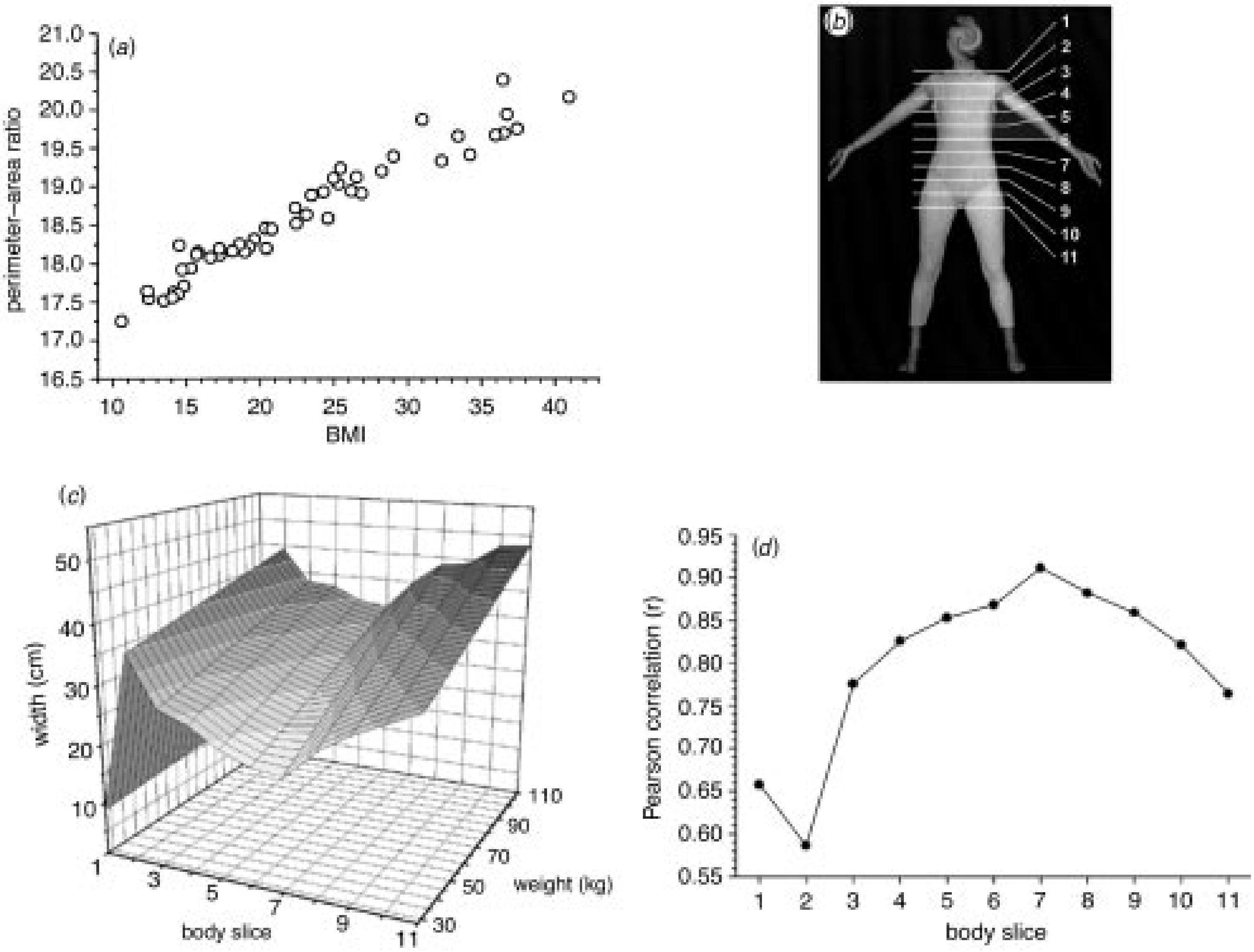

Figure 4. (*a*) A plot of perimeter–area ratio (PAR) against BMI for the 50 images in our study. See text for details. (*b*) A diagram illustrating the position of the 11 'slices' taken through the body of each of the 134 women's images. See text for details. (*c*) A 3D plot of the change in size of the slices with changing BMI across the 134 female images. (*d*) A plot of the *r* values from the Pearson's correlations between individual slices and the BMI values of the bodies from which the slices are taken. The results show a good correlation for slice width with BMI, particularly for the waist and lower body slices.

our results so at odds with previous findings? The answer seems to lie in the line-drawn stimuli used by Singh. The figures are in three series running across the page: thin, normal and fat. Within each series, the BMI of each of the four figures is supposed to be held constant, while its WHR is varied. However, this is not the case. Within a series, the line-drawn figures are modified by altering the width of the torso around the waist; this alters not only the WHR, but also the apparent BMI. As the value of the WHR rises, so does that of the apparent BMI. This can be shown by calculating the PAR of each of Singh's figures and plotting these values against WHR (see figure 5*a*); the two measures are clearly correlated ($r \geqslant 0.95$ for each of the three series). As a result, the change in the attractiveness of the figures can be accounted for equally well by a change in BMI (PAR).

In the present study, by using images of real women, both BMI and WHR were known precisely and their effects could be estimated separately. Under these appropriately controlled circumstances, BMI emerges as the major factor in determining sexual attractiveness.

In a more recent study, Tassinary & Hansen (1998) noted that Singh modified WHR by altering waist width, but only picked up the fact that he covaried WHR with waist width, not that he also changed apparent BMI. As a result, they produced a set of line-drawn figures in which they altered WHR by modifying either waist width or hip width independently. Unfortunately, their images were flawed in a similar way to Singh's: changes in both waist width and hip width were correlated with apparent BMI. This covariation can be quantified by using PAR, as it was with Singh's images, and used to predict Tassinary & Hansen's (1998) results. They used three sets of figures: heavy, moderate and light. Within these weight categories they modified WHR by changing waist or hip width. The changes in PAR are significantly correlated with both changing waist width and changing hip width ($r \geqslant 0.95$ for both). The largest change in PAR is with changing hip width (see figure 5*b*,*c*). This is because when Tassinary & Hansen alter hip width they also change the width of the thighs, producing a significant change in PAR at the same time. However, not only do they modify PAR within a specific weight category, where BMI is supposed to be constant, but they also overlap their weight categories. In their 3×3 matrix, the top left-hand image has a higher PAR (i.e. has a higher apparent

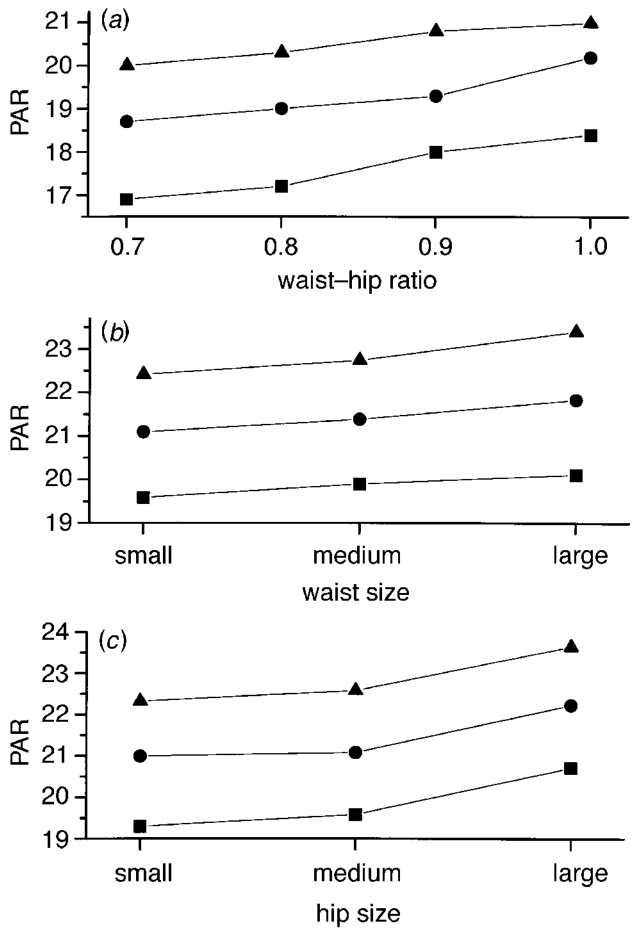

Figure 5. (*a*) A plot of WHR against PAR for the 12 images used by Singh (1994*a*). The data for the three weight groups are plotted separately. (*b*) A plot of WHR changed by altering waist-width against PAR for the line-drawn figures produced by Tassinary & Hansen (1978). (*c*) A plot of WHR changed by altering hip width against PAR for the line-drawn figures produced by Tassinary & Hansen (1978).

weight) than the bottom right-hand image of the next weight category up.

These findings allow us to predict that, in the attractiveness ratings of these images, although weight will emerge as an important factor, its effect size will be dissipated by the overlap in weight categories and the within-category variation. We can also predict that hip width will emerge as an important factor (apparently independent of weight) as it is covaried with a significant change in the apparent weight of the figures, whereas waist width, which is covaried with a much smaller change in weight, will be of less importance. This is exactly the results that Tassinary & Hansen report.

4. DISCUSSION

These results suggest that BMI is the primary determinant of the attractiveness of female bodies. It accounts for more than 70% of the variance in our analyses, whereas WHR accounts for little more than 2%. Furthermore, we provide evidence of a plausible visual cue to BMI (PAR) that provides an accurate visual proxy of BMI on which judgements of mate selection could be based. We suggest that the importance attributed to WHR in previous studies is likely to be an artefact of covarying WHR with apparent BMI. When both WHR and BMI are known for images of real women, their effects can be estimated separately, and BMI emerges as the most important factor.

There are clear advantages to using BMI as a basis for mate selection: BMI is closely correlated with health and fertility. In a recent cohort study, 115 195 women were followed over a period of 16 years. The lowest mortality rate (for all causes) was associated with BMIs close to 19 (Manson *et al.* 1995). Although representing the 'normal' range as defined by Bray (1978), women whose BMI fell between 19.0 and 24.9 had a 20% increase in relative risk of mortality. At still higher values of BMI, relative risk of mortality accelerated considerably: 33% increase in relative risk for BMIs of 25.0–26.9; 60% increase in relative risk for BMIs of 27.0–28.9 and over 100% increase in relative risk for BMIs of 29–32. A high BMI also has a negative impact on fertility (Reid & Van Vugt 1987; Frisch 1988; Brown 1993; Lake *et al.* 1997). At the opposite end of the scale, a BMI below 19 has a negative impact on both health and reproductive potential (Frisch 1988; Kaplan 1990; Reid & Van Vugt 1987; Lake *et al.* 1997). Fertility is particularly strongly affected, being reduced to zero at very low BMI, when women become amenorrhoeic. Put together, the evidence suggests that the balance between the optimal BMI for health and fertility is struck at around a value of 18–19, which, in this study, is also the preferred BMI for attractiveness.

There is evidence that body-fat distribution, as measured by WHR, plays a role in fertility. For example, Hartz *et al.* (1984) found that both BMI and WHR were positively related to irregularity in menstrual cycles, and Zaadstra *et al.* (1993) reported that both BMI and WHR were important predictors of conception in an artificial insemination programme. However, we would argue that the linkage of WHR with fertility is far weaker than that of BMI with fertility, and this may be one of the reasons that WHR may be such a poor predictor of attractiveness. For example, there is a considerable overlap in the WHRs of populations of normal women and anorexic patients (Tovée *et al.* 1997). The latter are amenorrhoeic. So a woman with an effective fertility of zero can have the same WHR as a woman with normal fertility. We therefore suggest that, although a WHR of 0.7 may represent the most fertile fat distribution for a given BMI, women with the same WHR but different BMIs can differ radically in health and reproductive potential. This suggests that there may exist a hierarchy of cues used to determine the attractiveness of a potential partner. BMI may be used as a primary 'screening criterion' to select the most attractive (i.e. healthiest and most fertile) women from a range of possible partners, and then other secondary factors such as body shape, including WHR, may be used to discriminate between these attractive individuals.

In addition to BMI and WHR, there are other features that may play a role in female physical attractiveness. Perhaps the best known of these is the degree of symmetry shown by a body. It is suggested that small deviations in bilateral symmetry (a phenomenon called fluctuating asymmetry (FA)) arise owing to developmental stress (such as from disease or parasites) and that these developmental stresses will have a negative impact on an individual's health and fitness (Thornhill & Gangestad 1996). As when selecting a mate, one wishes to choose an individual with good health and fertility, it is suggested that if one were sensitive to FA, it could be used as an index of a potential partner's suitability. Several studies have suggested that a symmetrical human face is more attractive than an asymmetrical one (see, for example, Gangestad *et al.* 1994; Thornhill & Gangestad 1995). However, other studies have suggested that facial symmetry is actually perceived as less attractive than asymmetry, because perfect symmetry appears abnormal in an environment where asymmetry is normal (Swaddle & Cuthill 1995; Kowner 1996). A study of bodies by Manning (1995) suggested that the degree of body asymmetry was positively correlated with body weight, and thus FA might play a role in the perception of attractiveness with changing BMI. Our own studies correlating the FA of a body (excluding the face) with its perceived attractiveness found no significant effect in a rating experiment, but did find a significant effect in a two-alternative forced-choice task (Tovée *et al.* 1999). This result suggests that although symmetry is a significant factor in determining physical attractiveness (excluding faces) under some circumstances, it is a comparatively subtle cue compared with BMI or even WHR.

The male university undergraduates who rated these female images for attractiveness are reasonably intelligent, young, Caucasian, middle-class Britons. Their criteria for female attractiveness may have arisen from a specific class or cultural bias, or as a result of selection pressures acting on their ancestors favouring a specific set of preferences. How may we differentiate these alternatives? Evolutionary psychology does allow that local psychological adaptations may exist in human populations and that individuals with different preferences may exist in a population owing to frequency-dependent selection (Thornhill & Gangestad 1996); nevertheless, a good working proof of a psychological adaptation is its universal nature. That is, the same behaviour or preferences should be found in individuals across the whole human population, regardless of class or culture. The next step in exploring the cues to female physical attractiveness must therefore be a cross-cultural study to determine how widely these preferences are held in the human population. There may be variation in the relative importance of BMI and WHR, as well as in the values that are regarded as the most attractive. For example, the most attractive WHR is reported to be 0.7, a value with which our study concurs. However, several studies have suggested that women with a higher WHR (and higher levels of free testosterone) are more likely to give birth to boys (Manning *et al.* 1996; Singh & Zambarano 1997). So it may be that, in societies where male children are particularly valued, such higher WHR values may be more attractive.

In conclusion, we can say that whether or not these preferences arose from cultural bias or evolutionary pressure, they will still have consequences for fitness and reproductive potential in mate selection, and a man who bases his judgement on BMI will optimize his chances of choosing a healthy and fertile partner.

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