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Visual perception of female physical attractiveness

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On the basis of visual assessment of figure drawings and front/profile images, past researchers believed that the waist–hip ratio (WHR) and the body mass index (BMI) were two putative cues to female physical attractiveness. However, this view was not tested on three-dimensional (3D) female images. In the present study, 3D images of 31 Caucasian females having varying body weights (BMI ranged from 16 to 35) were shown to 29 male and 25 female viewers, who were asked to rate the physical attractiveness. The results showed that the body volume divided by the square of the height, defined as volume height index (VHI), is the most important and direct visual determinant of female physical attractiveness. In determining the female attractiveness, human observers may first use VHI as a visual cue, which is also a key indicator of health and fertility owing to its strong linear relation to BMI. To fine-tune the judgement, observers may then use body proportions, the most important of which are the ratio of waist height over the chin height (WHC) (a measure of the length of legs over total tallness) and the deviation of WHR from the ideal ratio. It also appears that the effect of the body's physical parameters on the perception of female physical attractiveness conforms to Stevens' power law of psychophysics.

Keywords: female physical attractiveness; body mass index; volume height index; body shape; deviation of waist–hip ratio; waist height–chin height ratio

1. INTRODUCTION

The study of a body's physical attractiveness is important to evolutionary psychology and the understanding of beauty. The fundamental questions here are: how do we judge beauty and what are the physical cues for the assessment of attractiveness? Are these cues, if any, related to health and reproduction?

On the issue of female attractiveness, a lot of research work has been carried out on the ratio of the circumference (or width) of the waist to circumference (or width) of the hips, waist–hip ratio (WHR) (Singh 1993*a*,*b*, 1994*a*,*b*, 1995; Furnham *et al.* 1997, 1998). In Singh's studies (1993*a*,*b*, 1994*a*,*b*, 1995), a set of line-drawn figures of women's bodies with varying WHR and arranged in three categories: underweight, normal and overweight, were presented to a panel of viewers for rating the attractiveness. Singh found that men and women in the age range of 18–85 years regarded normal weight female figures with low WHR (0.7) as more attractive than those illustrating figures with a higher WHR who had the same or lower body weight. Also the normal weight figures were judged more attractive than the underweight, who were more attractive than the overweight. Additionally, an overweight woman with a low WHR was judged to be more attractive than a slim woman with a high WHR. Singh's findings were supported by Furnham *et al.* (1997), who also found that WHR is the most parsimonious measure of body physical attractiveness. An optimal WHR for attractiveness of 0.7 was suggested (Singh 1993*a*,*b*, 1994*a*,*b*, 1995; Furnham *et al.* 1997, 1998). Furnham *et al.* (1998) further investigated the effect of breast size on the judgement of female attractiveness. He found that the effect was dependent on the overall body fat and WHR. For females having a low WHR, large breasts enhanced attractiveness ratings (ARs), whereas for females having a high WHR, the reverse was true. The importance of WHR as a predictor of female attractiveness was believed to be due to its strong relationship with female health (Singh 1993*a*,*b*; Folsom *et al.* 1993) and fertility (DeRidder *et al.* 1990; Zaastra *et al.* 1993).

More recently, however, Tovée *et al.* (1998, 1999, 2002) and Tovée & Cornelissen (1999, 2001) discovered that weight scaled for height (the body mass index (BMI)) is a far more important determinant of attractiveness than WHR. BMI also has a strong impact on health and reproductive potential. Their analysis (Tovée *et al.* 1999) showed that BMI accounted for 73.7% of the ARs, whereas WHR accounted for only 2.3%. They believed that the visual cue of BMI was the perimeter–area ratio (PAR) (the path length around the perimeter of a figure divided by the area within the perimeter) and the overestimation of the importance of WHR in Singh's findings was due to the fact that the WHR of the line-drawn figures in Singh's approach was covaried with BMI.

Given the fact that WHR is an important cue of fertility, Tovée & Cornelissen (2001) believed that the reason for WHR being a poor predictor of attractiveness might be due to the difficulty in accurately judging WHR. Tovée *et al.* (2002) further argued that features such as WHR may be used to discriminate broad categories, such as male from female or pregnant from non-pregnant women (a between-category discrimination), and discrimination within the category of potential partners may use cues such as BMI and other cues such as the proportions of the body or body shape. These arguments are speculative and debatable.

Tovée *et al.* (1999, 2002) and Tovée & Cornelissen (2001) derived their findings from visually rating the attractiveness of front and side views of photo images and through multiple linear regression analysis with possible

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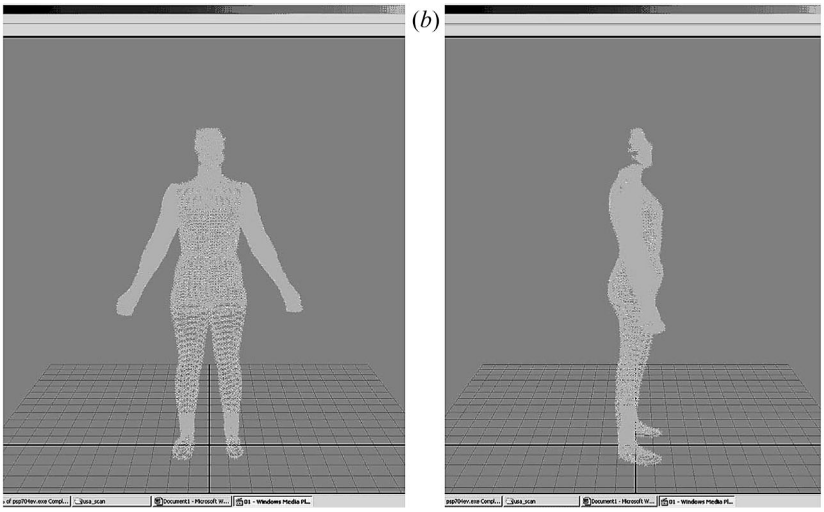

Figure 1. (*a*) An example of a movie clip in the stage of starting. (*b*) An example of a movie clip in the stage of 5 s.

explanatory variables of attractiveness including BMI and WHR. Could the findings of Tovée *et al*. be caused by the limitation in viewing the female images only in front and side views, the limitations of linear regression models or only limited body parameters included in the analysis? The present study was therefore initiated to extend and examine Tovée's findings by viewing three-dimensional (3D) images of the female body, obtaining 3D body measurements and analysing the data using different mathematical models.

2. SAMPLES AND METHODS

Thirty-one Caucasian females were scanned using a $[TC]^2$ body scanner (Davis 2001) to obtain 3D body measurements, which were then used to create short movie clips by Maya software for viewing (one front view and one side view are shown in figure 1*a*,*b*) and rating the attractiveness. The females wore tight-fitting body underwear during scanning. The underwear has little effect on the original body shape of the female. Each movie clip was standardized in the following ways.

(i) Each movie clip used the same camera view (view point) with the same distance, position and angle.
(ii) The female image in each movie clip was placed in the same position.
(iii) All 3D female images for the visual assessment were scaled in the same fixed proportion to the real size.
(iv) Each female image rotated 360° automatically in a clockwise direction and at the same speed (the time for completing 360° automatic rotation was 20 s).
(v) The female images were in wire-frame display format, so the effect of skin appearance was eliminated.
(vi) The heads of the female images were obscured.
(vii) The resolution of the images was 1280×1024.
(viii) For good visibility, the background colour of the movie clips was grey, and the colour of female images was blue.
(ix) All movie clips were presented using Windows Media Player.
(x) All movie clips were displayed on the same 18.5-inch liquid crystal display monitor.
(xi) Viewers rated the images independently.

Fifty-four Hong Kong Chinese raters (29 male, 25 female) were invited to rate the 31 wire-frame female body images in terms of attractiveness after viewing the movie clips. The attractiveness was rated on a 1 to 9 scale: from 1 being least attractive to 9 being most attractive. The average age of the male raters was 23.4 years old with a standard deviation of 0.92 years old. The average age of the female raters was 22.0 years old with a standard deviation of 0.2 years old. Except for two male teachers, all raters were students in fashion and textiles. For the male raters, the standard deviation of ratings ranged from 0.33 to 1.42; and for the female raters, the standard deviation ranged from 0.37 to 2.11. Multiple linear regression and the associated stepwise variable selection method were applied to analyse the relationship between the ARs and the female body's physical parameters.

3. RESULTS ANALYSIS

(a) *Body mass index and waist–hip ratio versus female attractiveness rating*

Figure 2*a*,*b* plots the average ARs for male viewers and female viewers versus BMI, respectively. The BMI of the female images included in our study ranged from 16 to 35 kg m^{-2}. Compared with Tovée's data, our data do not have a BMI of less than 16, which represents underweight female bodies. It is clear from figure 2*a*,*b* that the relationship between BMI and AR is nonlinear and female bodies having lower BMI values tend to have higher ARs within the range of female bodies investigated. This is in agreement with the results of Tovée *et al.* (1999) after excluding those data representing underweight female bodies.

Figure 3*a*,*b* plots the average ARs for male viewers and female viewers versus WHR, respectively. It illustrates a weak negative correlation between the attractiveness and WHR, again in agreement with the findings of Tovée *et al.* (1999, 2002).

We used the same multiple linear regression model that Tovée *et al.* (1999) and Tovée & Cornelissen (2001) used for analysing the data, except we did not include age as an independent variable because no such information was available (age was not found to be an important factor

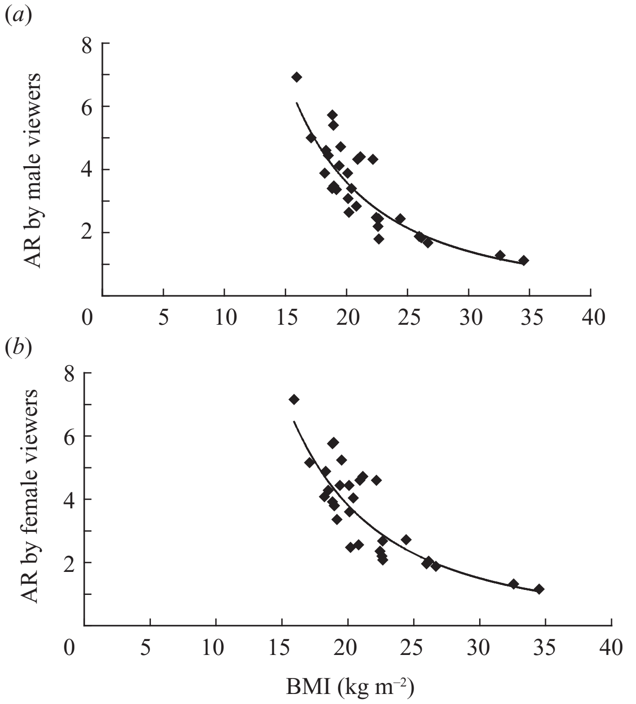

Figure 2. (*a*) Plot of AR for male viewers as a function of BMI. (*b*) Plot of AR for female viewers as a function of BMI.

by Tovée *et al.*). The regression model can be expressed as follows:

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4, \tag{3.1}$$

where y is average AR, a is the intercept, x_1 is WHR, x_2 is BMI, x_3 is BMI^2 and x_4 is BMI^3.

Using SPSS for the regression analysis, we obtained the following model for the average ARs by male viewers:

$$y = 48.679 - 4.668x_1 - 4.445x_2 + 0.155x_3 - 0.002x_4, \tag{3.2}$$

with $r^2 = 0.7421$, $p < 0.05$.

Both BMI and WHR were significant predictors ($p < 0.05$). The total variance explained by this model was 75.8%. BMI accounted for 72.7% of the variance, whereas WHR accounted for only 1.4%. These results are similar to those reported by Tovée *et al.* (1999), in which the total variance explained by their model having similar independent variables was *ca*. 76%, with BMI accounting for 73.7% and WHR accounting for 2.3% of the variance.

The regression model as expressed by equation (3.1) may not be the ideal model for the relationship between the ARs and BMI and WHR. As a logarithmic trend appears prominent from figure 2*a*,*b*, we explored the following model:

$$y = a + b_1x_1 + b_2x_2, \tag{3.3}$$

where y is a logarithm of AR, x_1 is log(WHR), and x_2 is log(BMI). No individual variable for log(BMI)^2 or log(BMI)^3 is necessary, as they are already included in log(BMI). Using SPSS, we can obtain the following:

$$y = 3.314 - 0.888x_1 - 2.212x_2, \tag{3.4}$$

with $r^2 = 0.821$, $p < 0.15$.

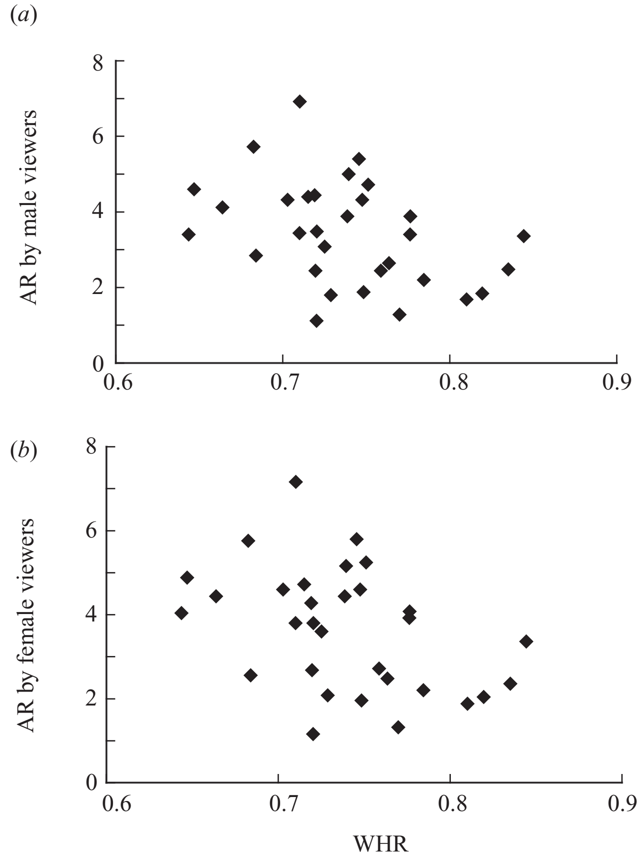

Figure 3. (*a*) Plot of the relationship between the AR for male viewers and the WHR. (*b*) Plot of the relationship between the AR for female viewers and the WHR.

The total variance explained by the new model was improved to 82.1%, with log(BMI) accounting for 80.4% and log (WHR) accounting for the additional 1.7%.

This analysis confirms the dominance of BMI in determining female physical attractiveness, and further reveals that the relationship between attractiveness perception and BMI or WHR could be logarithmic in form, which coincides with Stevens' power law of psychophysics (Goldstein 1999). For the relationship between perception and physical stimulus, Stevens proposed the following relationship:

$$P = cS^m, \tag{3.5}$$

where P is the perception, c is a constant, S is the intensity of physical stimulus and m is a power constant. Therefore, we have

$$\log(P) = \log(c) + m\log(S). \tag{3.6}$$

When more than one stimulus exists, equation (3.6) can be extended as

$$\log(P) = \log(c) + m_1\log(S_1) + m_2\log(S_2) + \ldots + m_n\log(S_n). \tag{3.7}$$

Comparing the values of r^2 of equation (3.4), which coincides with Stevens' power law, and equation (3.2), which is based on a polynomial relationship, it is clear that the model based on Stevens' power law fits the data better than the polynomial relationship.

(b) *Volume height index versus female attractiveness rating*

The calculation of BMI requires the knowledge of body weight. As it is difficult to measure body weight visually, BMI must be estimated from some visual cues. Tovée *et al.* (1999) believed that BMI was predicted from the PAR. They found that PAR has a strong linear relationship with BMI ($r = 0.97$, $p < 0.0001$). In viewing the 3D image of the female bodies as in our experiments or in real situations, PAR is less convincing as the viewers do not view the front area, but the entire 3D shape.

We postulated that the viewer might estimate the body weights of the female bodies from their volumes. As the heads of the female images were obscured for the purpose of our work, the relevant body volume should be the volume excluding the head. Similarly, the relevant height for the body attractiveness assessment should be the height excluding the head. To examine this, we conducted multiple linear regression analysis using the following model:

$$y = a + b_1x_1 + b_2x_2, \quad (3.8)$$

where y is log(AR), x_1 is log(V) (the unit of V is cubic feet) and x_2 is log(HC) (the unit of HC is feet).

When the average ARs of male observers were used in the analysis, we obtained the following equation:

$$y = -4.431 - 1.367x_1 + 2.954x_2, \quad (3.9)$$

with $r^2 = 0.9010$, $p < 0.05$.

When the average ARs of female observers were used in the analysis, we obtained the following equation:

$$y = -4.046 - 1.382x_1 + 2.750x_2, \quad (3.10)$$

with $r^2 = 0.8899$, $p < 0.05$.

Equation (3.9) can be rewritten as

$$\begin{aligned} y &= -4.431 + 2.954\log(\text{HC}) - 1.367\log(V),\\ &= -4.431 - 1.367[\log(V) - 2.16\log(\text{HC})],\\ &= -4.431 - 1.367\log(V/\text{HC}^{2.16}). \end{aligned} \quad (3.11)$$

Similarly, equation (3.10) can be rewritten as

$$y = -4.046 - 1.382\log(V/\text{HC}^{1.99}). \quad (3.12)$$

From equations (3.11) and (3.12), it is convincing that female ARs for either male or female observers are largely determined by the ratio of volume over the square of chin height. We therefore define a new parameter called volume height index (VHI):

$$\text{VHI} = V/\text{HC}^2, \quad (3.13)$$

where V is the volume of the female body excluding the head, and HC is the chin height (the body height from chin to the bottom of the feet).

Should our postulate be correct, VHI should give a better prediction of female attractiveness than BMI.

Figure 4*a*,*b* shows the relationship between log(AR) for female observers and male observers, and log(VHI) respectively. As can be seen, the relationships are almost linear with r^2 being 0.9001 and 0.8899, respectively. In other words, *ca*. 90% of the variance of the ARs was explained by the VHI alone. Compared with BMI, which explains *ca*. 80% of the variance, VHI clearly gives a better prediction of female attractiveness. Based on this finding, it is reasonable to believe that human observers may

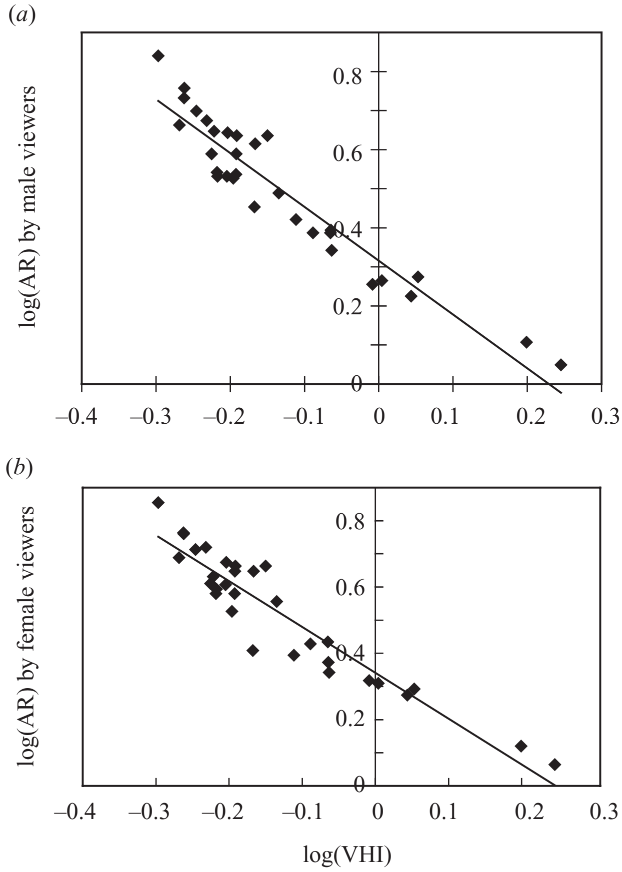

Figure 4. (*a*) Plot of log(VHI) versus log(AR) for male viewers. $y = -1.378x + 0.3156$; $r^2 = 0.9006$. (*b*) Plot of log(VHI) versus log(AR) for female viewers. $y = -1.3818x + 0.3409$; $r^2 = 0.8899$.

assume the density of the human body as being constant and use VHI as an estimation of BMI in the visual assessment of female physical attractiveness.

Furthermore, from the results shown in figure 4*a*,*b*, there appears to be no significant difference between the results of male observers and those of female observers. In other words, there is good agreement in the perception of female physical attractiveness between male and female viewers. This is in agreement with Tovée & Cornelissen's (2001) results and consistent with the mate-selection theory.

(c) *Relationship between attractiveness rating and other physical parameters of the female body*

VHI is in fact a ratio of average cross-sectional area over the height of the body. It would be highly unlikely that VHI alone determines the physical attractiveness of females, as this would mean a tubular body would be as attractive as a more curvaceous body and someone with a short leg would be as beautiful as someone with a long leg.

To understand how other female body parameters apart from VHI affect the perception of female physical attractiveness, almost all key body measurements of the female subjects obtained using the [TC]2 body scanner and their ratios were included in the multiple regression analysis as potential independent variables to determine their significance in predicting female attractiveness.

The body measurements considered were, in the vertical direction: waist height, hip height, seat height,

Table 1. Prediction models of log(AR).

viewer gender	model number	variable	coefficients	*t*-test	total r^2
AR rated by male viewers	1	constant	0.316	19.968	0.901
		log(VHI)	−1.378	−16.213	
	2	constant	0.707	4.210	0.917
		log(VHI)	−1.440	−17.255	
		log(WHC)	2.580	2.340	
	3	constant	0.678	4.375	0.932
		log(VHI)	−1.402	−17.887	
		log(WHC)	2.965	2.889	
		log(AWHR)	-6.548×10^{-2}	−2.465	
AR rated by female viewers	1	constant	0.341	20.313	0.890
		log(VHI)	−1.382	−15.313	
	2	constant	0.851	5.027	0.917
		log(VHI)	−1.463	−17.391	
		log(WHC)	3.361	3.025	
	3	constant	0.821	5.288	0.933
		log(VHI)	−1.423	−18.129	
		log(WHC)	3.759	3.657	
		log(AWHR)	-6.776×10^{-2}	−2.546	

abdomen height, thigh height, calf height, crotch height, stomach height, bust height and under bust height; and in the horizontal direction: seat circumference, abdomen circumference, maximum thigh circumference, neck circumference, shoulder slope length, across chest, stomach circumference and bust circumference.

The ratios considered were the ratios of all vertical measurements over the chin height, the ratios of all horizontal measurements over the waist circumference, WHR, AWHR (i.e. abs(WHR–0.7); the absolute value of WHR minus the commonly believed 'ideal' WHR of 0.7), and VHI.

All of the above parameters and the dependent variable, AR, were taken as a logarithm before applying linear regression analysis. We applied a stepwise variable selection method in Spss to reject or retain explanatory variables. The possible prediction models are listed in table 1.

The parameters, which are significant at $p < 0.05$ ($t = 2.04$) were found to be log(VHI), log(WHC) (the ratio of waist height over chin height) and log(AWHR). The rest of the parameters were rejected. Among the three selected parameters, log(VHI) accounted for 90.1% of the variance of log(AR) of male viewers (or 89.0% of the variance of log(AR) of female male viewers), log(WHC) accounted for 1.6% (or 2.7%), and log(AWHR) accounted for 1.5% (or 1.6%). These results suggest the following.

(i) VHI is a dominant factor in the perception of female physical attractiveness. Without being underweight, a smaller VHI tends to increase female physical attractiveness.
(ii) For an ideal body, VHI alone is not sufficient, body proportion and shape parameters such as WHC and AWHR are important. A greater WHC (proportionally long legs), and a smaller AWHR (less deviation from the ideal value of 0.7), tend to enhance female physical attractiveness.
(iii) The effects of VHI, WHC and AWHR on the AR do not vary greatly with the gender of the viewer.

4. DISCUSSION

In viewing 2D female drawings or images, Tovée *et al.* (1999) believed that the PAR was used as a visual cue to BMI, given the fact PAR has a strong linear relationship with BMI. In viewing 3D female body images or real female bodies, the use of PAR became unnecessary: human observers could use other visual cues for assessing attractiveness. We have shown that the body volume divided by the square of the height, VHI, explained *ca.* 90% of the variance of average ARs, more than BMI, which was *ca.* 80%. It is reasonable to believe that VHI is the most important direct visual determinant of female physical attractiveness.

Our findings are consistent with that of Tovée *et al.* (1999, 2002) and Tovée & Cornelissen (2001), who found that BMI is a dominant determinant of female physical attractiveness, because VHI and BMI should have a strong linear relationship. The female images in Tovée *et al.* (1999, 2002), Tovée & Cornelissen (2001) and our experiments were Caucasian women. However, the viewers in Tovée's experiments, who rated the female images for attractiveness, were young Caucasian university undergraduates, whereas the viewers in our experiments were Hong Kong Chinese university undergraduates. It is therefore reasonable to believe that there is some cross-culture consistency in the perception of female physical attractiveness, although there can be exceptions. For example, Marlowe & Westman (2001) found that Hadza men (hunter-gatherers in Tanzania) prefer high WHRs: possibly because they like heavier women, because under their conditions of life, obesity is not an issue and heavier women are also reproductively more healthy.

Tovée *et al.* (1999) showed that the most attractive females had a BMI value between 18 and 19, which coincides with the optimal value for health and fertility. In our work, the highest AR was given to the female having the lowest BMI at 16. Could this mean that Hong Kong Chinese youth prefer a thinner Caucasian female? We cannot be sure about this speculation owing to the limited number of female images having relatively low BMI values in our study. However, the possibility is that Chinese youth's perception of the ideal body is influenced by the norms they experience. These norms are that the Chinese females in Hong Kong are probably thinner than western females, or Chinese youth's perception of the Caucasian female is very much influenced by a 'Barbie doll' type of image.

BMI (weight/height^2) is a widely used parameter for measuring body fitness and has been considered by Tovée *et al.* (1998, 1999) and Tovée & Cornelissen (1999, 2001) as a determinant of female physical attractiveness. But why weight/height^2, not weight/height$^{1.2}$, weight/height$^{1.5}$, weight/height$^{2.5}$, etc.? Through the derivation of equation (3.12), it is interesting to find that volume/height^2 (generally proportional to weight/height^2) was obtained by regression of natural data. It appears that weight/height^2 is not simply a choice of convenience, but there may be perceptual reasons. Volume/height^2 is in fact the ratio of the average cross-sectional area over the height, or in other words, the ratio of horizontal dimension over the vertical dimension. Is it because humans like the simplicity of this ratio in judging physical attractiveness? Further work on this aspect could be very interesting.

From the analysis of our data (without underweight female bodies), there appears to be a linear relationship between the logarithm of the perception of AR and the logarithm of body physical parameters. It appears that Stevens' power low of psychophysics also applies to the perception of female physical attractiveness.

It is also interesting to find that WHR or log(WHR) was rejected as a possible explanatory variable in the stepwise variable selection of the multiple linear regression analysis. However, log(AWHR) (AWHR = abs[WHR–0.70]) was retained as a significant ($p < 0.05$) explanatory variable. During the computational analysis, we have tried to use log(abs[WHR–0.60]), log(abs[WHR–0.61]), … log(abs[WHR–0.80]); log(abs[WHR–0.70]) was found to give the most significance. This suggests two things: (i) the ideal value of WHR is 0.7 as suggested by (Singh 1993*a*,*b*, 1994*a*,*b*, 1995; Furnham *et al.* 1997, 1998); and (ii) it is the deviation from the ideal WHR not the actual value of WHR that influences the perception of female physical attractiveness.

From the relative importance of VHI, WHC and AWHR in determining female attractiveness, it is reasonable to believe that human observers first use VHI as a visual cue to assess attractiveness, which is also a key factor of health and fertility. To fine-tune the judgement, observers then use body proportions, the most important of which are the ratio of waist height over the chin height (a measure of the length of the legs over total tallness) and the deviation of the ratio of waist over hip from the ideal ratio.

Mate-selection theory suggests that women have a very precise and accurate idea of what men find attractive (Tovee & Cornelissen 2001). As a result, the ratings of the female images by men and women will not produce any gender differences. In agreement with the findings of Tovee & Cornelissen (2001), our results support the mate-selection theory in that there is no significant difference in the visual perception of female physical attractiveness between female and male viewers.

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REFERENCES

Davis, K. 2001 [TC]^2's body scanner. See http://www.tc2.com/RD/RDBody.htm.

DeRidder, C. M., Bruning, P. F., Zonderland, M. L., Thijssen, J. H. H., Bonfrer, J. M. G., Blankenstein, M. A., Huisveld, L. A. & Erich, W. B. M. 1990 Body fat mass distribution, and plasma hormones in early puberty in females. *J. Clin. Endocrinol. Metab.* **70**, 888–893.

Folsom, A. R., Kaye, S. A., Sellers, T. A., Hong, C., Cerhan, J. R., Potter, J. D. & Prineas, R. J. 1993 Body fat distribution and 5-years risk of death in older women. *J. Am. Med. Assoc.* **269**, 483–487.

Furnham, A., Tan, T. & McManus, C. 1997 Waist-to-hip ratio and preferences for body shape: a replication and extension. *Psychol. Med.* **38**, 327–336.

Furnham, A., Dias, M. & McClelland, A. 1998 The role of body weight, waist-to-hip ratio, and breast size in judgments of female attractiveness. *Sex Roles* **39**, 311–326.

Goldstein, E. B. 1999 *Sensation and perception*. Pacific Grove, CA: Brooks/Cole Publishing Company.

Marlowe, F. & Westman, A. 2001 Preferred waist-to-hip ratio and ecology. *Pers. Indiv. Diff.* **30**, 481–489.

Singh, D. 1993*a* Adaptive significance of female physical attractiveness: role of the waist-to-hip ratio. *J. Personality Social Psychol.* **65**, 293–307.

Singh, D. 1993*b* Body shape and women's attractiveness: the critical role of waist-to-hip ratio. *Hum. Nature* **4**, 297–321.

Singh, D. 1994*a* Is thin really beautiful and good? Relationship between waist-to-hip ratio (WHR) and female attractiveness. *Pers. Indiv. Diff.* **16**, 465–481.

Singh, D. 1994*b* Ideal female body shape: the role of body weight and waist-to-hip ratio (WHR) ratio. *Int. J. Eat. Disord.* **16**, 283–288.

Singh, D. 1995 Female health, attractiveness and desirability for relationships: role of breast asymmetry and waist-to-hip ratio. *Ethol. Sociobiol.* **16**, 465–481.

Tovée, M. J. & Cornelissen, P. L. 1999 The mystery of female beauty. *Nature* **399**, 215–216.

Tovée, M. J. & Cornelissen, P. L. 2001 Female and male perceptions of female physical attractiveness in front-view and profile. *Br. J. Psychol.* **92**, 391–402.

Tovée, M. J., Reinhardt, S., Emery, J. L. & Cornelissen, P. L. 1998 Optimal BMI and maximum sexual attractiveness. *Lancet* **352**, 548.

Tovée, M. J., Maisey, D. S., Emery, J. L. & Cornelissen, P. L. 1999 Visual cues to female physical attractiveness. *Proc. R. Soc. Lond.* B **266**, 211–218. (DOI 10.1098/rspb.1999.0624.)

Tovée, M. J., Hancock, P. J. B., Mahmoodi, S., Singleton, B. R. R. & Cornelissen, P. L. 2002 Human female attractiveness: waveform analysis of body shape. *Proc. R. Soc. Lond.* B **269**, 2205–2213. (DOI 10.1098/rspb.2002.2133.)

Zaastra, B. M., Seidell, J. C., Van Noord, P. A. H., Velde, E. R., Habbema, J. D. F., Vrieswijk, B. & Karbaat, J. 1993 Fat and fecundity: prospective study of effect of body fat distribution on conception rates. *Br. Med. J.* **306**, 484–487.