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The estimation of body mass index and physical attractiveness is dependent on the observer's own body mass index

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A disturbance in the evaluation of personal body mass and shape is a key feature of both anorexia and bulimia nervosa. However, it is uncertain whether overestimation is a causal factor in the development of these eating disorders or is merely a secondary effect of having a low body mass. Moreover, does this overestimation extend to the perception of other people's bodies? Since body mass is an important factor in the perception of physical attractiveness, we wanted to determine whether this putative overestimation of self body mass extended to include the perceived attractiveness of others. We asked 204 female observers (31 anorexic, 30 bulimic and 143 control) to estimate the body mass and rate the attractiveness of a set of 25 photographic images showing people of varying body mass index (BMI). BMI is a measure of weight scaled for height ($kg\,m^{-2}$). The observers also estimated their own BMI. Anorexic and bulimic observers systematically overestimated the body mass of both their own and other people's bodies, relative to controls, and they rated a significantly lower body mass to be optimally attractive. When the degree of overestimation is plotted against the BMI of the observer there is a strong correlation. Taken across all our observers, as the BMI of the observer declines, the overestimation of body mass increases. One possible explanation for this result is that the overestimation is a secondary effect caused by weight loss. Moreover, if the degree of body mass overestimation is taken into account, then there are no significant differences in the perceptions of attractiveness between anorexic and bulimic observers and control observers. Our results suggest a significant perceptual overestimation of BMI that is based on the observer's own BMI and not correlated with cognitive factors, and suggests that this overestimation in eating-disordered patients must be addressed directly in treatment regimes.

Keywords: anorexia nervosa; bulimia nervosa; body-mass estimation; body image; attractiveness; body mass index

1. INTRODUCTION

Eating disorders are an increasing problem in the female population. The proportion of women who suffer from these conditions continues to rise and current therapeutic regimes have only a limited success in treating these conditions (e.g. Garner & Garfinkel 1997; Fairburn *et al.* 1999), particularly in anorexia nervosa where the long-term mortality rate is more than 10% (DSM-IV, American Psychiatric Association 1994). To be able to treat these conditions more effectively we need a better understanding of their central features. A key feature of the diagnostic criteria for both anorexia nervosa and bulimia nervosa seems to be a distorted evaluation of personal body mass and size (DSM-IV, American Psychiatric Association 1994).

Many researchers have suggested that there are two components of body-image dysfunction: a perceptual body-size distortion and a 'cognitive–evaluative' dysfunction (e.g. Cash & Deagle 1997; Gardner 1996; Slade 1988; Cash & Brown 1987). The perceptual distortion is defined when an observer is unable to gauge her body size accurately and the cognitive distortion is when an observer can accurately estimate her size but may be dissatisfied with her size, shape or some other aspect of her appearance (Cash & Deagle 1997; Gardner 1996). In this study we focus primarily on the perceptual distortion, which has been difficult to quantify reliably (e.g. Slade 1988, 1994). It is uncertain whether overestimation is a causal factor in the development of these eating disorders or is merely a secondary effect of having a low body mass. If overestimation is a secondary effect of weight loss, then it might be expected to develop as body mass declines. If women of a range of body-mass values (from emaciated to obese) are tested for body-mass estimation, it should be possible to determine whether or not the degree of estimation is linked to the body mass of the subject.

Additionally, we will determine whether the overestimation of body size is specific to the observer's own body or whether it extends to estimating the size of other women's bodies. If the overestimation is purely a perceptual deficit, a problem with making the fine within-category judgements necessary to assign a body to a particular body-mass value, then one might expect this overestimation to extend to the perception of other women's bodies.

The putative overestimation of body mass has implications for the perception of physical attractiveness. Body mass is usually measured in terms of the body mass index (BMI), which is a measure of weight scaled for height with units of $kg\,m^{-2}$ (Bray 1978). Most studies suggest that the BMI of a subject is an important factor in how both men and women perceive female physical attractiveness

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(e.g. Singh 1993, 1994; Henss 1995; Furnham *et al.* 1997; Tovée *et al.* 1998, 1999, 2000; Tovée & Cornelissen 1999, 2000). Therefore the appraisal of another person's attractiveness requires an observer to estimate accurately the BMI of a subject. An overestimation of another person's BMI would systematically shift an observer's perception of that person's body attractiveness, just as an overestimation of the observer's own BMI would shift her perception of her own attractiveness. For example, if an observer has a BMI of 20, which is regarded as more attractive than a BMI of 22, then an overestimation by two BMI units could result in the observer believing herself to be more unattractive than she is. This could produce a strong pressure on the observer to reduce her BMI through dieting to increase her own perceived attractiveness.

To explore these questions we have asked 204 female observers (including anorexic and bulimic observers), whose body mass ranged from emaciated to obese, to rate a set of 25 pictures of women for BMI and attractiveness. They also estimated their own BMI from a picture of themselves (they did not rate their own attractiveness as this was considered too stressful for the eating-disordered observers).

2. METHODS

Observers (31 female anorexic, 30 female bulimic and 143 female control) rated the size and attractiveness of a set of 25 colour photographic images of women. The eating-disordered patients were recruited from the Eating Disorder In-Patient Service at the Royal Victoria Infirmary, Newcastle Upon Tyne, and were diagnosed on the basis of DSM-IV (American Psychiatric Association 1994). The controls were age matched and drawn from GP lists in the same geographical areas as our eating- disordered subjects. The controls had no history of eating disorders and scored within the normal range on a set of screening questionnaires including the Beck Depression Inventory (BDI), the Beck Anxiety Inventory (BAI), the Rosenberg Self-Esteem Scale (RSE), the Body Shape Questionnaire (BSQ), the Eating Disorder Beliefs Questionnaire (EDBQ) and the Eating Disorders Examination Questionnaire (EDEQ) (Beck *et al.* 1961; Rosenberg 1965; Cooper *et al.* 1987; Cooper *et al.* 1997; Fairburn & Beglin 1994). A summary of the data is shown in table 1. All observers tested within the normal range for visual acuity using the Snellen chart.

To generate the images for rating, consenting women were videotaped standing in a set pose at a standard distance, wearing close-fitting grey leotards and leggings. Images were then frame-grabbed and stored as 24-bit colour pictures. The images varied in BMI from 11.4 to 34.3. Five of the images came from each of the BMI categories (Bray 1978): emaciated (below 15), underweight (15–20), normal (20–25), overweight (25–30) and obese (above 30). Examples of these images are shown in figure 1. The waist–hip ratio (WHR) of the images was kept within a comparatively narrow range (from 0.74 to 0.93, with a mean of 0.82, s.d. = 0.05) to minimize any potential effect of WHR on the size or attractiveness ratings. The faces of the images were obscured. In addition to our set of 25 images, the observers estimated the body mass of an image of themselves. This allows us to make a comparison between the estimation of the observer's own image and the estimation of other women's bodies.

Table 1. *Descriptive statistics (given as mean ± s.d.) for the three observer groups*

(BMI, body mass index; BDI, Beck depression inventory; BAI, Beck anxiety inventory; RSE, Rosenberg self-esteem; EDBQ, eating disorders beliefs questionnaire; BSQ, body shape, EDEQ-WC, the weight concern subscale of the eating disorders examination questionnaire; EDEQ-SC, the shape concern subscale of the eating disorders examination questionnaire.)

	controls	anorexics	bulimics
age	28.3 ± 9.2	27.2 ± 8.0	27.5 ± 7.3
BMI	22.5 ± 3.7	14.9 ± 1.9	23.5 ± 5.7
BDI	5.8 ± 6.4	28.4 ± 13.8	22.2 ± 12.3
BAI	8.1 ± 7.6	21.9 ± 13.4	20.5 ± 14.4
RSE	30.5 ± 4.8	17.9 ± 4.7	21.9 ± 4.7
EDBQ	18.2 ± 15.4	65.4 ± 19.7	58.6 ± 21.1
BSQ	79.4 ± 29.1	133.4 ± 34.7	147.5 ± 34.1
EDEQ-WC	8.9 ± 8.9	23.9 ± 7.6	26.5 ± 7.1
EDEQ-SC	12.9 ± 9.8	32.9 ± 7.8	33.4 ± 6.9
age of onset	—	18.7 ± 6.1	17.7 ± 4.0
duration of illness	—	8.5 ± 6.6	9.8 ± 6.4

The observers estimated body mass on a marked linear scale corresponding to the BMI scale and annotated with the relevant labels: emaciated, underweight, normal, overweight and obese. The position of the mark was then measured on the scale and expressed as estimated BMI (BMI_{est}) allowing ready comparison with the actual values. We asked observers to estimate BMI rather than simple weight because we wanted to use a measure of body mass scaled to the size of the body. One can be tall and thin or short and fat, and still have the same weight. We felt, therefore, that BMI is a better representation of the degree of fat deposition on a body. Previous studies have suggested that female observers should be very accurate in judging other women's BMI and there are several putative visual cues they could use (Tovée *et al.* 1998, 1999; Tovée & Cornelissen 2000). These include the perimeter–area ratio (which is correlated with BMI at better than 0.97) or just simple relative lower-body widths (Tovée *et al.* 1999; Tovée & Cornelissen 2000). For example, relative waist width is correlated with BMI at better than 0.95. So using these simple visual cues it should be possible to judge BMI accurately, and as can be seen from figure 2, the BMI_{est} values from control observers match very closely the actual BMI values of the images. Observers rated attractiveness on a scale of 0 (least attractive) to 9 (most attractive). The order of presentation of the 25 images was randomized and subjects were presented with the entire set twice. The first run through was used to make observers aware of the range of variability of body features represented in the images. Only on the second run through were observers asked to rate them.

3. RESULTS

(a) *The estimation of other women's BMI*

Most control observers were able accurately and consistently to estimate the BMI of the women in the 25 pictures (figure 2). When estimating the BMI of the 25 images, the estimates show only slightly reduced accuracy at the extremes of the BMI range (i.e. the observers were generally good at estimating the BMI of female images across the range of BMI values). As the

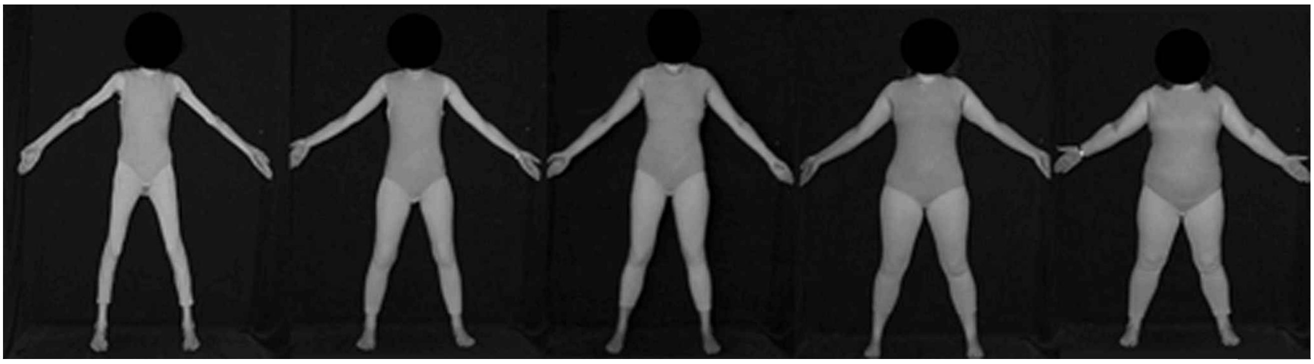

Figure 1. Examples of the images used in this study. Each image is from one of the five BMI categories. The image on the far left is from the emaciated category and has a BMI of 13.52. The next image is from the underweight category and has a BMI of 17.34. The next image is from the normal range and has a BMI of 22.07. The fourth image is from the overweight category and has a BMI of 28.01. The final image is from the obese category and has a BMI of 34.05.

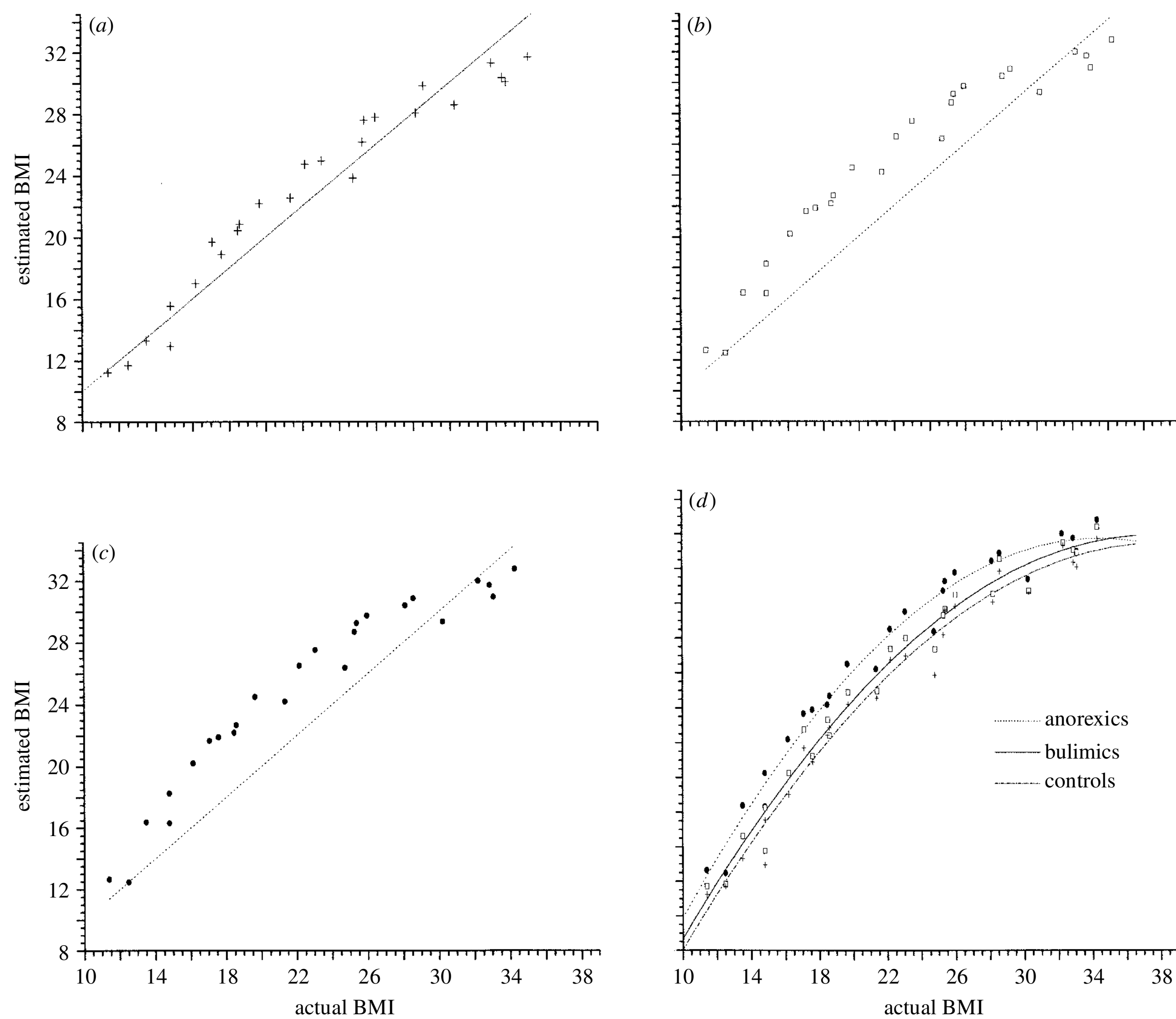

Figure 2. Estimated BMI of each image plotted against the actual BMI of the image for (*a*) control observers, (*b*) bulimic observers and (*c*) anorexic observers. The dotted line indicates the equality line (i.e. the line upon which estimations would fall if they were completely accurate). (*d*) For comparison purposes, we show the plots of all three observer groups together. The estimates by the anorexic observers are represented by filled circles and a dotted line, the bulimic observers by open squares and a solid line, and the controls by crosses and a dashed line.

estimates by the observers in all three groups seem to show the same pattern (i.e. a slight 'dip' at the extremes of the BMI range of the images), when we compare the average estimations of the BMI by observers in the three groups, the dip at the extremes should average out.

The control observers were very accurate in their estimate of the BMI (BMI_{est}) of the 25 images, overestimating on

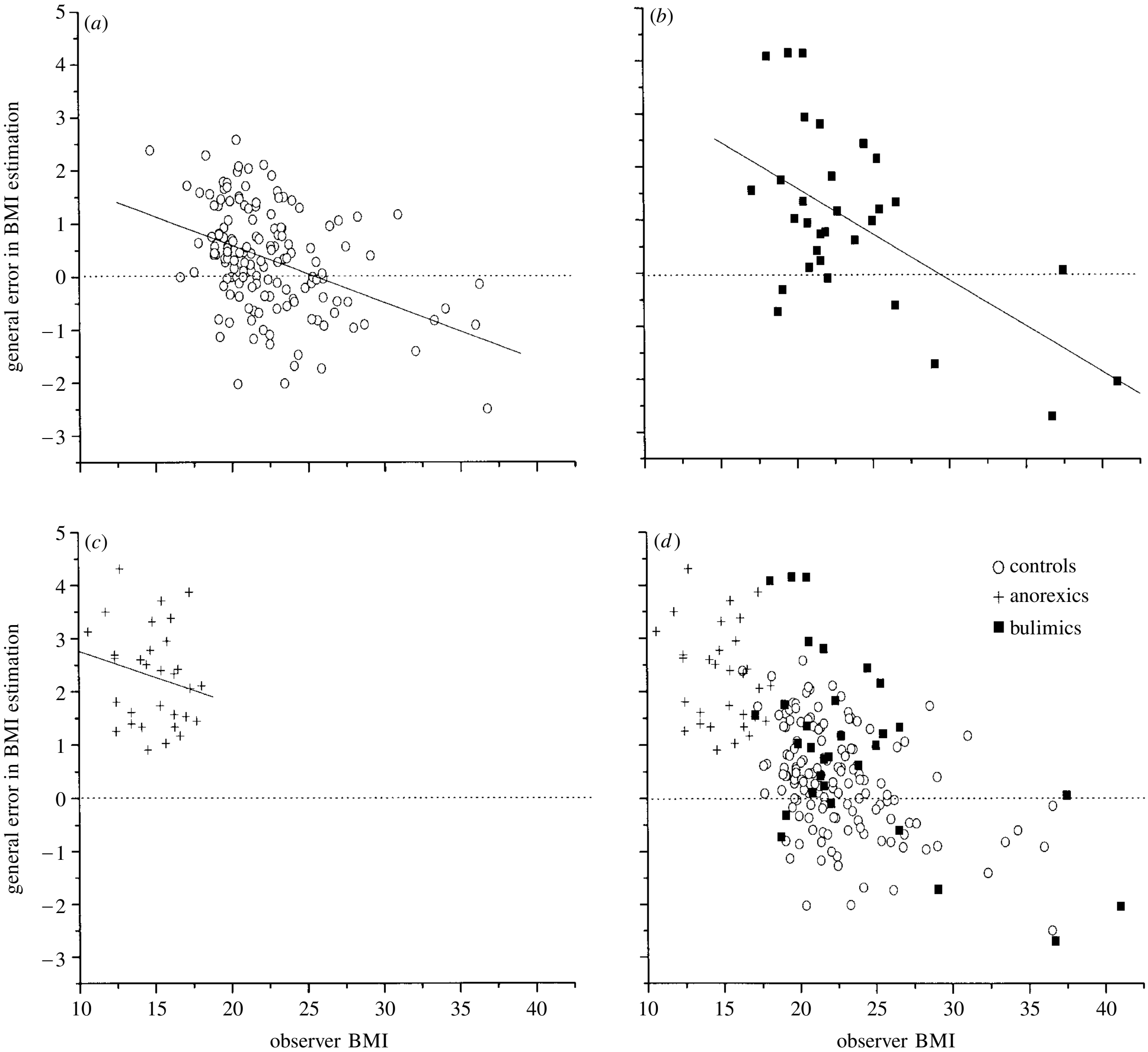

Figure 3. The average overestimation of the BMI of the 25 figures plotted against the observer's BMI for (*a*) control observers, (*b*) bulimic observers, (*c*) anorexic observers and (*d*) all three groups of observers. Each point represents the average of the 25 judgements made by a particular observer. As can be seen, there is a continuum of error in body-mass estimates with changing observer BMI.

average by only 0.35 BMI_{est} units. However, the anorexic observers overestimated the BMI_{est} of the images by an average of 2.29 BMI_{est} units and the bulimic observers overestimated by 0.99 BMI_{est} units. These values are all significantly different from each other (one-way ANOVA, $F_{2,201} = 15.92$, $p < 0.0001$; *Post Hoc* test, Games-Howell $p < 0.001$).

However, the overestimation does not represent a qualitative difference between anorexic and bulimic observers and control observers. Instead the degree of overestimation seems to be inversely proportional to the BMI of the observer. This can be illustrated by plotting the average overestimation by each observer against the observer's own BMI (figure 3). There is a significant correlation between the overestimation and the observer's own BMI (Pearson correlation, d.f. = 202, $r = -0.59$, $p < 0.0001$). As the BMI of the observer declines, the overestimate of the BMI of another person rises. The estimates by the anorexic and the bulimic observers can be seen as part of a continuum based on observer BMI, rather than as qualitatively separate estimates. This relationship can also be seen within the individual observer groups. There is a significant correlation between the estimated BMI and the observer's own BMI for both control and bulimic observers (controls, d.f. = 141, $r = -0.591$, $p < 0.0001$; bulimics, d.f. = 28, $r = -0.586$, $p < 0.0001$). The data from the anorexic observers show the same trend but the correlation does not reach statistical significance (d.f. = 29, $r = -0.203$, $p = 0.273$). The fact that the correlation does not reach significance in the anorexic group may be partially due to the fact that these observers all fall within a narrow range of BMI values, compared to the BMI values of the other observers in the control and bulimic groups.

(b) *The estimation of personal BMI*

We also asked our observers to estimate the BMI of their own bodies. The controls overestimated by

1.42 BMI_{est} units, the bulimics by 2.43 BMI_{est} units and the anorexics by 4.28 BMI_{est} units. The overestimations by the three groups are all significantly different (one-way ANOVA, $F_{2,201} = 33.98$, $p < 0.0001$; *Post Hoc* test, Games-Howell show that anorexics and bulimics are different from controls at the level of $p < 0.0001$ and anorexics are different from bulimics at $p < 0.05$). These overestimates of own body are all significantly higher for each observer group than the average overestimates for other women's bodies (independent-samples *t*-test assuming unequal variances, control observers, $t = 4.73$, d.f. = 279, $p < 0.0001$; bulimic observers, $t = 2.09$, d.f. = 56, $p < 0.05$; anorexic observers, $t = 3.14$, d.f. = 56, $p < 0.005$). Again these overestimates may not actually represent qualitative differences between control, bulimic and anorexic observers. Instead, if one correlates the overestimates against the BMI of the observers in all three observer groups, then the degree of overestimation is significantly inversely correlated with the BMI of the observer (Pearson correlation, d.f. = 202, $r = -0.629$, $p < 0.0001$). If one looks at this relationship in each observer group separately, degree of overestimation is inversely correlated with the observer BMI for both the control and bulimic observers (controls, d.f. = 141, $r = -0.697$, $p < 0.0001$; bulimics, d.f. = 28, $r = -0.807$, $p < 0.0001$) (figure 4*a*,*b*). Interestingly, the overestimation is actually positively correlated with observer BMI in the anorexic group (anorexics, d.f. = 29, $r = 0.496$, $p = 0.005$). In figure 2, we have already illustrated that there is a 'dip' in the estimation of other women's BMI at the extreme ends of the BMI range (i.e. an observer tends to underestimate the BMI of very low or very high BMI subjects). So one might expect anorexic subjects (who have very low BMI values) to underestimate their own BMI values. However, although there is a 'dip' in the overestimation of personal BMI at low BMI values, most of the anorexic observers still overestimate their own BMI (figure 4*c*). Only four out of 30 anorexic observers actually underestimated their own BMI.

Careful inspection of the estimates by anorexic observers of their own BMI suggests the existence of two distinct data clouds (i.e. two separate subgroups). One subgroup makes higher overestimates (observers whose BMI falls between 14 and 18) and one subgroup makes more accurate estimates (observers whose BMI is below 14). The latter group of 21 observers overestimate BMI, on average, by 1.1 BMI_{est} units and the former group of ten observers overestimate by 5.3 BMI_{est} units. The two estimates are significantly different (independent-samples *t*-test, d.f. = 29, $t = -4.268$, $p < 0.0001$). If one treats these two subgroups as a single population, then there is a positive correlation between overestimation of personal BMI and the observer's BMI, as the BMI < 14 subgroup is significantly more accurate. However, this does not represent a smooth change in accuracy of personal BMI estimation across the anorexic population as a whole, but a sharp discontinuity between the two subgroups. If one examines the correlation between observer's BMI and the accuracy of estimation within these two subgroups separately, then there is no significant correlation for the BMI > 14 group (d.f. = 19, $r = 0.069$, $p = 0.766$) but there is a significant negative correlation for the BMI < 14 group (d.f. = 8, $r = -0.706$, $p < 0.05$). However, there is no obvious separation into subgroups based on overestimation of other women's bodies. The degrees of overestimation in the two subgroups in this case are not significantly different (BMI > 14 subgroup overestimated by 2.49 BMI_{est} units, the BMI < 14 subgroup by 2.18 BMI_{est} units; independent-samples *t*-test, d.f. = 29, $t = 0.864$, $p = 0.416$). The two subgroups are also not significantly different (at the level of $p < 0.05$) on any other variable such as the questionnaire results (BSQ, BDI, EDBQ, RSE, EDEQ shape-concern scale, EDEQ weight-concern scale, EDEQ eating-concern scale), average age, age of onset or duration of the condition.

(c) *The corrected estimate of personal BMI*

To separate a general overestimation from an overestimation specific to the observer's own body for each observer we decided to subtract the their overestimate of other women's bodies from their overestimate of personal BMI. As there is a 'dip' in accuracy in the estimation of BMI values at the extreme ends of the range, we decided not to subtract the average error in estimation for all 25 images. Instead, we subtracted the average for the five women in the same BMI category as each observer. For example, for an observer with a BMI in the emaciated range we subtracted their average estimation for the five images in the emaciated range, and so on. This produced values of 0.99 BMI_{est} units for controls, 1.12 BMI_{est} units for bulimics and 2.24 BMI_{est} units for anorexics. These values are again significantly correlated with personal BMI across all our observer groups (Pearson correlation, d.f. = 202, $r = -0.481$, $p < 0.0001$) and show a broad continuum of overestimation with changing BMI. However, looking at each observer group separately shows that although this relationship holds for the bulimic observers (d.f. = 28, $r = -0.701$, $p < 0.0001$) and controls (d.f. = 143, $r = -0.610$, $p < 0.0001$), there is a positive relationship between overestimation and observer's BMI for anorexic observers (d.f. = 29, $r = 0.573$, $p < 0.001$).

For the two anorexic subgroups, the pattern is unchanged from the unadjusted values. The BMI > 14 subgroup overestimates on average by 3.8 BMI_{est} units, and the BMI < 14 subgroup is more accurate, they slightly underestimate by on average 1.0 BMI_{est} unit. The two subgroups are significantly different in the accuracy of their estimation (independent-samples *t*-test, d.f. = 29, $t = -4.92$, $p < 0.0001$). The correlation between the accuracy of estimation and the observer's BMI is not significant for the BMI > 14 subgroup, (d.f. = 19, $r = 0.105$, $p = 0.649$) or for the BMI < 14 subgroup, although there is a strong trend toward a negative correlation (d.f. = 8, $r = -0.539$, $p = 0.108$).

(d) *Perceptual and cognitive measures*

In addition to estimates of BMI, our subjects completed several questionnaires designed to measure dissatisfaction with personal body size or shape. The results of these measures do not seem to be correlated with the error in estimating BMI. First, we correlated the accuracy of the estimates of other women's BMI by our three observer groups with the BSQ, the EDBQ and all seven subscales of the EDEQ (including the shape- and weight-concern subscales). None of the correlations reached the $p < 0.05$ level of significance. We then repeated the process, but

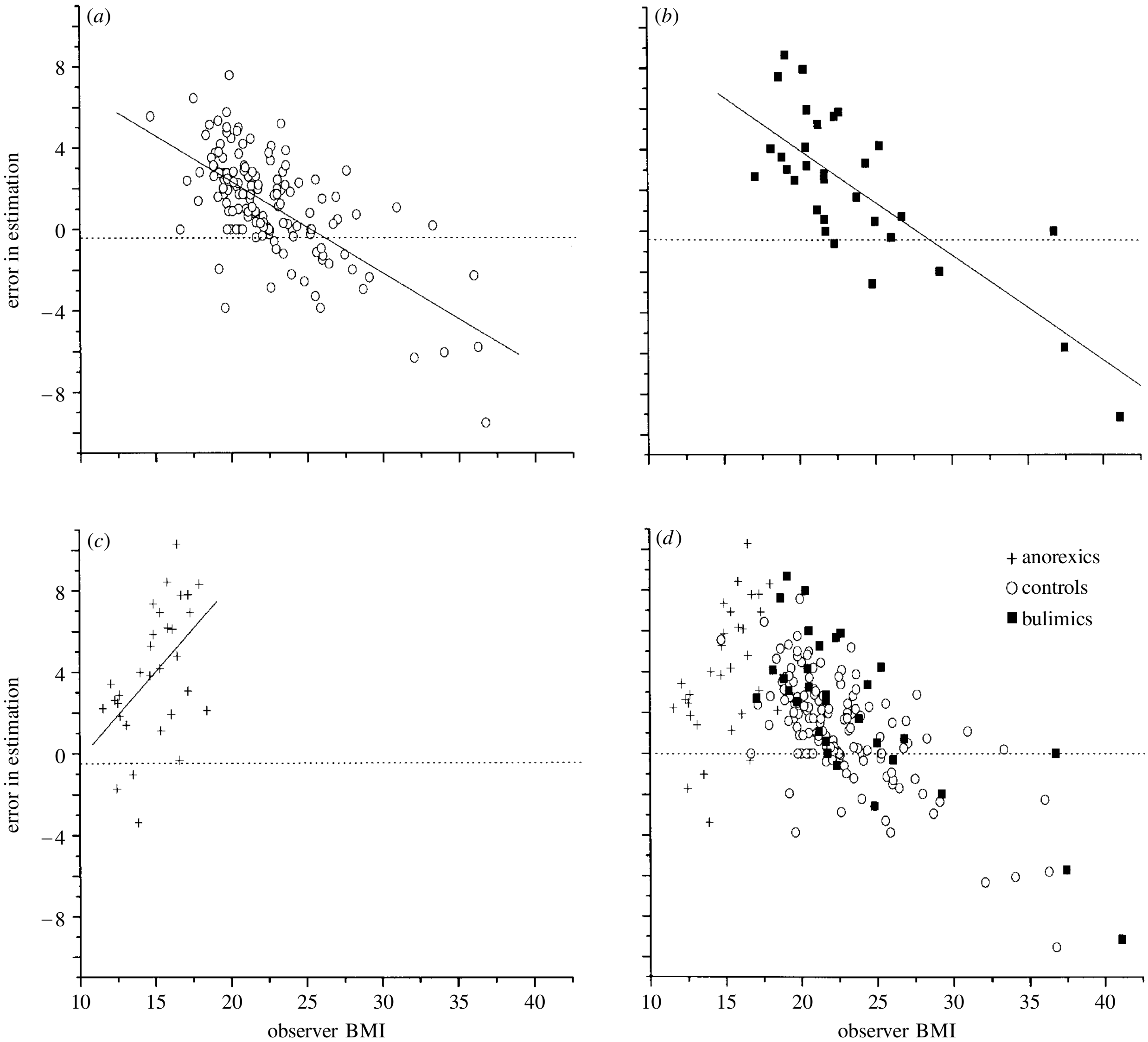

Figure 4. The overestimation of the observer's own BMI plotted against the observer's actual BMI for (*a*) control observers, (*b*) bulimic observers, (*c*) anorexic observers and (*d*) all three observer groups. Again, there seems to be a continuum of error in body-mass estimates with changing observer BMI.

correlating the questionnaire results against the accuracy of estimating personal BMI for each of our three observer groups. Once again, none of the correlations reached the $p < 0.05$ level of significance.

(e) *Accuracy of estimation and the mood of the observer*

It is possible that the apparent change in the accuracy estimation of both personal BMI and other women's BMI with the observer's own BMI is due to other factors, such as changing mood (e.g. Cohen-Tovée 1993). For example, if an observer is depressed, her performance at estimating BMI may suffer. However, the results of the questionnaires designed to assess mood do not correlate with the error in estimating BMI. First, we correlated the accuracy of the estimates of other women's BMI by our three observer groups with the BDI, the BAI and the RSE. None of the correlations reached the $p < 0.05$ level of significance. We then repeated the process, but correlating the questionnaire results against the accuracy of estimating personal BMI for each of our three observer groups. Once again, none of the correlations reached the $p < 0.05$ level of significance.

(f) *A neural substrate for the overestimation?*

It is possible that the increasing overestimation of BMI with decreasing observer BMI is linked to poor nutrition. The poor nutritional intake that leads to a lower BMI may also lead to the damage of cortical neurons and a lack of neurotransmitter substrates. Structural imaging of anorexic and bulimic subjects has shown irreversible brain shrinkage, which would be consistent with neuronal cell death (e.g. Lankenau *et al.* 1985; Krieg *et al.* 1989; Lauer *et al.* 1990; Lambe *et al.* 1997). Given that up to 50% of the human cortex is involved to some degree in the processing and analysis of visual information (e.g. Drury *et al.* 1996), it would be expected that the neural changes documented in low-BMI subjects would manifest themselves in their perceptual analysis of the visual cues to a body's BMI. If this is true, then one might expect the duration of the disease in anorexics or bulimics to be correlated with the magnitude of overestimation.

However, all the correlations between illness duration and the overestimation of other women's BMI and personal BMI failed to reach the $p < 0.05$ level of significance for both anorexic and bulimic observers.

(g) *Attractiveness and BMI*

BMI is an important component in the attractiveness of the female body (e.g. Tovée *et al.* 1998, 1999, 2000; Tovée & Cornelissen 1999, 2000) and inaccuracies in the estimation of BMI have serious implications for the perception of attractiveness. If the attractiveness of a body is dependent to some degree on an observer's estimate of her BMI, then a systematic overestimation of BMI will in turn systematically shift this perception of attractiveness. This is illustrated by the observers' attractiveness ratings for our set of 25 images. If one plots the attractiveness ratings against the real BMI of the images, the shape of the function is the same for all observers. However, the position of the peak of the curve (i.e. the most 'attractive' BMI) differs between individuals. To quantify this difference, we used a third-order polynomial regression to estimate the optimally attractive, or 'peak' BMI, for each subject's ratings (Tovée *et al.* 1999). If one first compares the average peak values for the anorexic, bulimic and control observers, the values are significantly different (one-way ANOVA, $F_{2,200} = 46.923$, $p < 0.0001$). The peak for the control observers is at 20.62 BMI units, which is significantly higher than that for both the bulimic observers at 19.84 BMI units and the anorexic observers at 17.98 BMI units (*Post Hoc* tests, Games-Howell and Tamhane, $p < 0.001$). The peak values for the anorexic and bulimic observers are also significantly different from each other (*Post Hoc* tests, Games-Howell and Tamhane, $p < 0.001$) (figure 5*a*,*b*). These differences in attractiveness seem to be based on the BMI of the individual observers within the groups, rather than a qualitative difference between groups. If one plots the position of the peak of the curve against the BMI of each observer, then the two are correlated (Pearson correlation, d.f. = 201, $r = 0.550$, $p < 0.0001$) (figure 6*a*). If one now plots the attractiveness ratings for the images not against their real BMI, but against the BMI estimated by each observer, the differences in the positions of the curves disappear (figure 5*c*,*d*). The peak values are now no longer significantly different for controls (21.17), bulimics (21.00) and anorexics (21.05) (one-way ANOVA, $F_{2,200} = 0.487$, $p = 0.615$). If one now plots the position of the peak of the curve based on estimated BMI against each observer's BMI, then the two are no longer correlated (Pearson correlation, d.f. = 201, $r = 0.078$, $p = 0.272$) (figure 6*b*); i.e. the BMI of the observer no longer predicts the BMI they find most attractive. This suggests that all three groups of observers agree on the attractiveness of a given BMI, the apparent differences seem to arise from errors in estimating the BMI of the women in our set of 25 images. Once the errors in estimation have been controlled for, there are no longer any differences in the attractiveness preferences.

(h) *Attractiveness and shape*

Body shape is also regarded as a significant cue to attractiveness (e.g. Singh 1993, 1994; Henss 1995; Furnham *et al.* 1997; Tovée *et al.* 1997, 1998, 1999): a more curvaceous body being regarded as more attractive. The range of body shapes in this study was comparatively narrow compared to the range of BMI values for the body images. However, there was some variation in shape. The WHR varied from 0.74 to 0.93, the waist–bust ratio (WBR) (a measure of upper-body shape) varied from 0.83 to 1.16 and the bust–hip ratio (BHR) (a measure of whether the body is an 'hour glass' shape or not) varied from 0.79 to 0.96. Although none of these features reached significance in a multiple regression to determine their relative importance for ratings of attractiveness, they are all significantly correlated with the ratings. This is true of all three groups of observers. There is a significant correlation of attractiveness with WHR (Pearson correlations, controls, d.f. = 141, $r = -0.302$, $p < 0.0001$; bulimics, d.f. = 28, $r = -0.335$, $p < 0.0001$; anorexics, d.f. = 28, $r = -0.349$, $p < 0.0001$), with WBR (controls, d.f. = 141, $r = -0.326$, $p < 0.0001$; bulimics, d.f. = 28, $r = -0.377$, $p < 0.0001$; anorexics, d.f. = 28, $r = -0.443$, $p < 0.0001$) and with BHR (controls, d.f. = 141, $r = 0.129$, $p < 0.001$; bulimics, d.f. = 28, $r = 0.178$, $p < 0.0001$; anorexics, d.f. = 28, $r = 0.282$, $p < 0.0001$). This suggests that all three groups prefer a more curvaceous body shape.

To explore further whether there are differences between observers in the three different groups we used multiple regression to carry out three pairwise comparisons between groups. In the models the group factor was classified using dummy variables. There was no effect of group for WHR, WBR or BHR at the $p < 0.05$ level of significance. These results would be consistent with a common internal representation of what constitutes an attractive body across all three groups. It is only the overestimation of body mass that shifts the apparent preferences of anorexic and bulimic observers.

4. DISCUSSION

The results show a clear pattern of overestimation of the BMI of other women's bodies by all three observer groups. This overestimation is inversely proportional to the observer's own BMI. So, although both anorexic and bulimic observers significantly overestimated compared to the control observers, this may not represent a primary feature of the anorexic and bulimic observers' clinical condition. Instead, it may be an extension of a trend towards overestimation of BMI with declining personal body mass that is already evident within the control group.

In bulimic and control observers, the magnitude of the overestimation of personal BMI is also inversely correlated with the observer's own BMI. The situation is more complex in anorexic observers. The average magnitude of overestimation by anorexic observers is significantly higher than for bulimic or control observers, which is consistent with previous studies (Slade 1988, 1994; Garner & Garfinkel 1997). However, across the whole anorexic observer group, the trend of overestimation is downward with decreasing BMI, rather than upward as is found in the other observer groups. This relationship is true for both for the 'raw' estimations and for the estimations corrected for the observer's estimation of five other bodies in the same BMI category (i.e. corrected for the accuracy of their general estimation of people with the

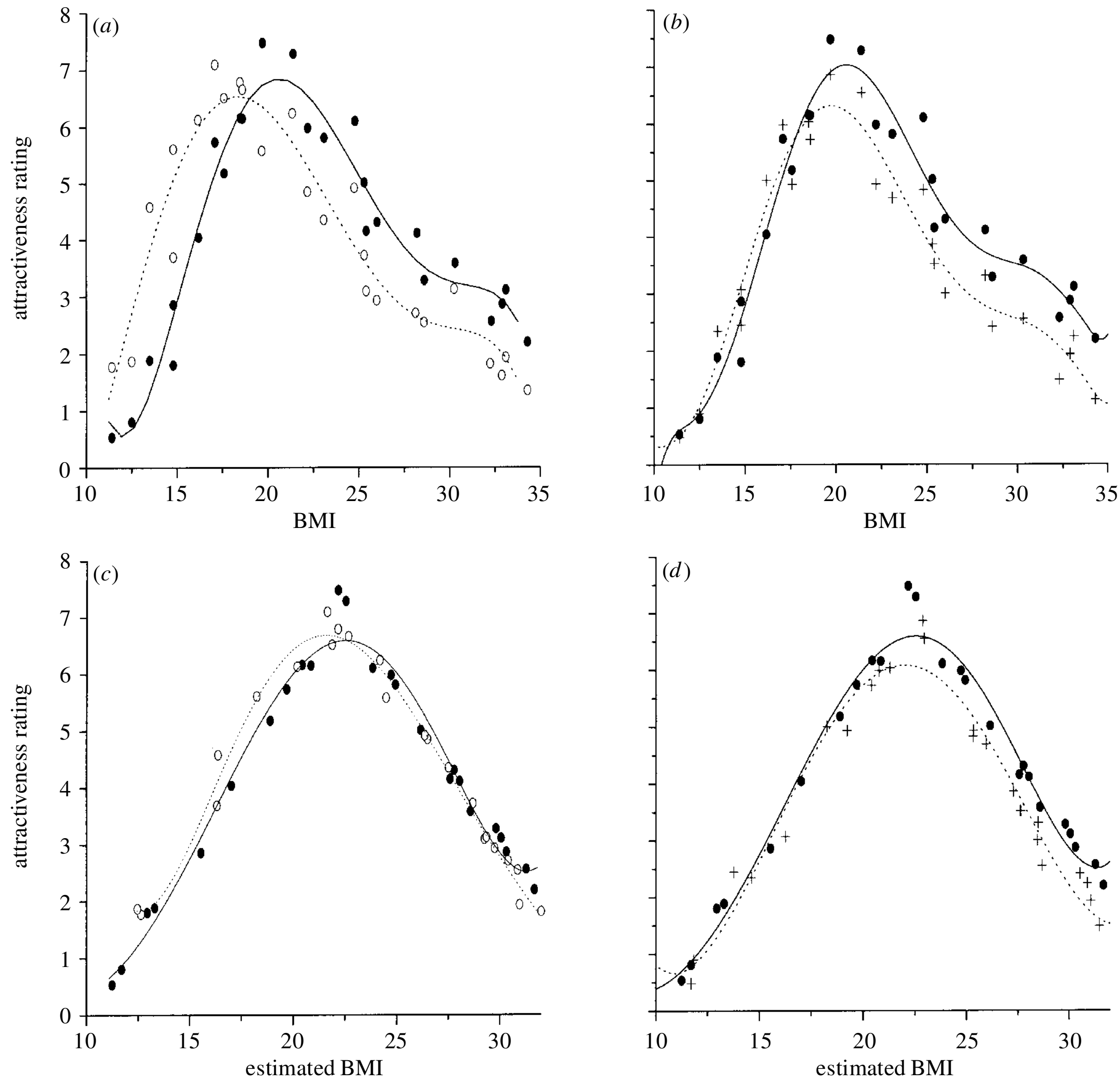

Figure 5. Attractiveness as a function of the actual BMI of each of the 25 images, as rated by (*a*) anorexic observers (open circles) and control observers (filled circles), and (*b*) bulimic observers (crosses) and control observers (filled circles). Each point represents the average rating by the observers in each observer group. A regression line for each function is superimposed. Attractiveness as a function of the estimated BMI of each of the 25 images, as rated by (*c*) anorexic observers (open circles) and control observers (filled circles), and (*d*) bulimic observers (crosses) and control observers (filled circles). Each point represents the average rating by the observers in each observer group. A regression line for each function is superimposed.

same BMI). So the change in the pattern of overestimation in anorexic observers (relative to bulimic and control observers) does not seem to be due to changes in the accuracy of estimating low-BMI bodies relative to higher-BMI bodies. However, this pattern may be due to the putative existence of two subgroups within the anorexic observers: those with a BMI < 14 and those with a BMI > 14. The former subgroup is significantly more accurate in estimating personal BMI than the latter subgroup. Several studies have suggested that those patients diagnosed with anorexia nervosa may not be a homogeneous group, but may display differences in aetiology and symptoms (e.g. Welch *et al.* 1990; DaCosta & Halmi 1992). However, the two subgroups in our study do not differ significantly in any of the questionnaire measures used to explore attitudes to food, body shape and size, or those assessing mood and anxiety. An alternative explanation for the differences in estimation could be that the BMI < 14 subgroup are all hospitalized, whereas the BMI > 14 subgroup are mainly out-patients. The BMI < 14 subgroup are therefore likely to be receiving considerably more psychiatric and psychological treatment and nutritional intervention. This treatment would include interventions aimed at addressing the overestimation of body size. Thus, the increased accuracy in personal body-size estimation in this subgroup may just reflect the impact of intensive treatment in an in-patient service. However, if this explanation is correct, one might expect significant differences in our questionnaire measures as well, which is not the case. Alternatively, it may be incorrect to propose the existence of two subgroups in our anorexic observer group, and the pattern of estimates in our comparatively small sample size may have led to a

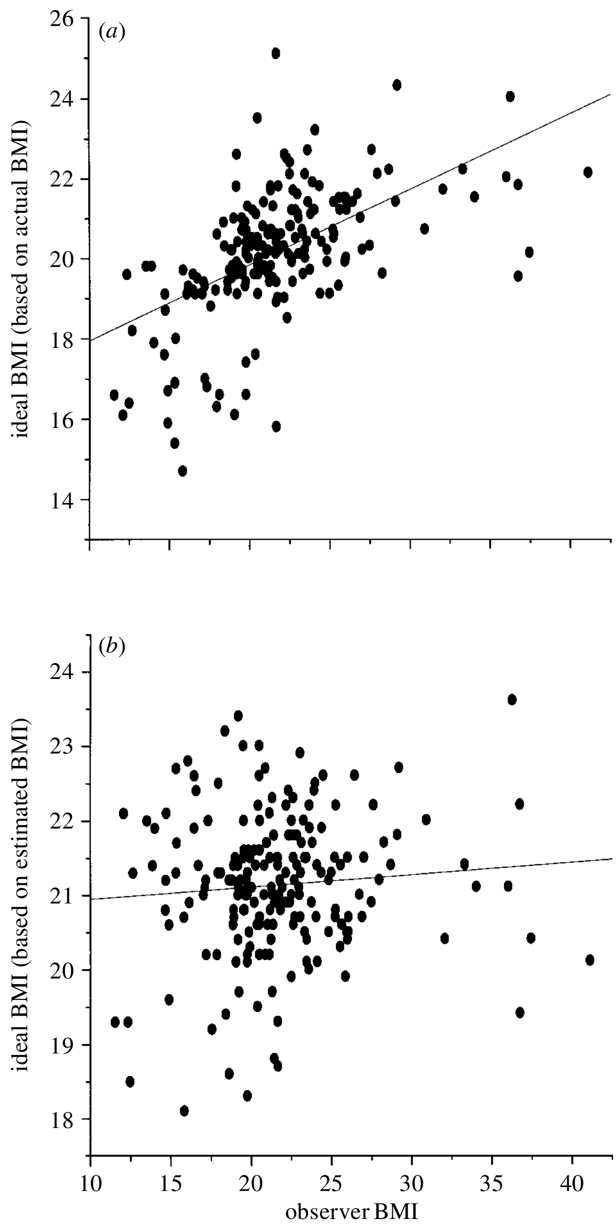

Figure 6. (*a*) The position of the peak of each attractiveness curve based on the actual BMI of the images plotted against each observer's BMI; the two are significantly correlated (Pearson correlation, $r = 0.550, p < 0.0001$). (*b*) The position of the peak of each attractiveness curve based on the estimated BMI plotted against each observer's BMI; the two are no longer correlated (Pearson correlation, $r = 0.078, p = 0.272$).

false impression that would be dispelled with a larger sample size.

The negative correlation between the overestimation of personal BMI and observer's BMI in the control and bulimic observers might provide a mechanism that acts to reinforce weight-loss behaviours in a positive feedback loop (i.e. weight loss causes you to overestimate BMI, shifting your perception of what is an attractive size and your perception of your own BMI, which in turn produces a pressure to lose further weight). This mechanism could be part of the pathway to developing an eating disorder and it could certainly be expected to be a maintaining factor.

It is interesting to note that as an observer's BMI increases much beyond the upper limits of the normal range (i.e. above a BMI of 24 units), she tends to underestimate the BMI of both her own and other bodies. This result is consistent with a previous report of underestimation of body weight by overweight women (Klesges 1983). This underestimation could potentially play a role in the process by which a person's body mass increases beyond the normal range, as a subject may underestimate any weight gain.

The degree of overestimation with changing BMI should not be overstated; it modulates the accuracy of BMI estimation rather than producing large shifts in accuracy. In the estimation of other women's BMI, if one looks within the 'normal' BMI range (20–25 BMI units), then the shift in estimation is less than 2.0 BMI units. Similarly, in the estimation of personal BMI, the shift in estimation is less than 1.0 BMI unit. It is only when one looks at the extremes of the BMI range in our observers (from a BMI of 11.53 to 41.12) that this change in observer BMI of 29.59 units produces dramatic changes the accuracy of estimation. For other women's BMI, the very low BMI observers overestimate by up to 4.31 BMI_{est} units, whereas the higher BMI observers underestimate by up to 2.69 BMI_{est} units (a range of 7.0 BMI_{est} units). For the estimation of personal BMI, the very low BMI observers overestimate by up to 10.3 BMI_{est} units, whereas the higher BMI observers underestimate by up to 9.5 BMI_{est} units (a range of 19.8 BMI_{est} units). So normally the effect of BMI on estimation is a modulating factor, rather than a controlling factor. Within the range of BMI values found in most people in the general population, the shift in estimation will not produce great differences in the perception of size and attractiveness. It is only when there is a steady and sustained drop in personal BMI that the misperception of body size becomes a potentially significant factor in maintaining dietary-control behaviour.

It is possible that the basis for the overestimation of BMI may lie in part with the neural changes associated with changes in body mass. Structural imaging studies of eating disordered patients have shown irreversible brain shrinkage, consistent with cell death, and this is likely to alter the functioning of the visual system (e.g. Lankenau *et al.* 1985; Krieg *et al.* 1989; Lauer *et al.* 1990; Lambe *et al.* 1997). So it is possible that the neural changes documented in low-BMI subjects would manifest themselves in the detection and analysis of the visual cues to the BMI of a body. However, the changes in perception cannot be easily explained by these neural changes. First, in the case of anorexic and bulimic observers, if the overestimation is a reflection of neural damage caused by dietary abnormalities, then the magnitude of the overestimation should correlate with the duration of the eating disorder (i.e. the length of time there has been severe dietary abnormalities). However, it does not. Second, for the estimation of other women's BMI, there is a continuum of misjudgement from overestimation in low-BMI observers through to underestimation in higher-BMI observers. Finally, for personal BMI, the degree of overestimation actually falls with decreasing BMI in anorexic observers. This suggests any explanation based on neural damage through malnutrition can only be part of the story.

As we have said earlier, it has been argued that there may be two components to body-image distortion: a perceptual distortion and a cognitive dissatisfaction (Cash & Brown 1987; Slade 1988, 1994; Cash & Deagle 1997). The putative cognitive component is usually measured by questionnaires, such as we have used, which assess the degree to which a subject is dissatisfied with her size, shape or some other aspect of her appearance. Consistent with our own findings, previous studies have suggested the two components are only weakly correlated, or not significantly correlated at all (e.g. Cash & Green 1986; Ben-Tovim *et al.* 1990; Hsu & Sobkiewicz 1991; Keeton *et al.* 1990). Additionally, although some aspects of the cognitive dissatisfaction seem to be linked to mood (e.g. Cohen-Tovée 1993), this is not the case for the overestimation reported here. This suggests that a perceptual dysfunction can arise independently from any cognitive dysfunction. The fact that the overestimation extends to other women's bodies is consistent with it being a purely perceptual error. If it were a cognitive deficit, perhaps a miscalibration of an internal representation of personal body mass and size, then it would be unlikely to extend to an overestimation of other women's bodies. However, if it were a perceptual deficit, a problem with making the fine within-category judgements necessary to assign a body to a particular body-mass value, then one might expect this overestimation to extend to the perception of other women's bodies, as we find here.

Our results suggest a significant perceptual component in body-image dysfunction, with a significant overestimation of both personal BMI and other women's BMI. The primary treatment of body-image disturbance in both anorexia nervosa and bulimia nervosa is through cognitive behavioural therapy (e.g. Rosen *et al.* 1989; Kearney-Cooke & Striegel-Moore 1997; Fairburn *et al.* 1999). It is possible that this treatment for eating disorders could be enhanced by addressing the perceptual problem directly, perhaps by giving a client feedback regarding her pattern of overestimation, via a BMI-estimation task such as that used here.

The results show that although anorexic and bulimic observers apparently find bodies with a significantly lower BMI more attractive than controls, these preferences seem to be by-products of their overestimation of BMI. Their internal representation of an attractive BMI seems to be the same as that of a control observer, but their overestimation systematically shifts this representation relative to the real BMI of a particular body.

Our results suggest that people of a similar BMI are likely to find each other attractive, and so there may be a positive assortment for BMI in human mate selection. A number of studies have investigated this area and they have indeed reported a weak to moderate correlation between intra-pair body mass of between 0.1 and 0.25 (for reviews, see Spuhler 1968; Allison *et al.* 1996). This correlation cannot be simply explained by factors such as similar environmental conditions or partner influence, as a recent study compared intra-pair body mass prior to marriage and cohabitation (Allison *et al.* 1996). After correcting for age, this study found a weak, but statistically significant, correlation of 0.13. Taken as a whole, these studies suggest a weak, but significant, effect of positive assortment for BMI in human mate selection.

The modulation of preferred BMI by personal BMI suggests an intriguing answer to the reports of differences in body-mass preferences for different cultures (e.g. Furnham & Nordling 1998; Craig *et al.* 1996; Yu & Shepard 1998, 1999; Wetsman & Marlowe 1999). Are these differences cultural? Or are they actually merely reflecting physical differences in the subjects tested? If the observers in one cultural group have an average BMI different to the observers in the comparison cultural group, then differences in preferred BMI would be expected. For example, Polynesians have been reported to find optimally attractive a body mass heavier than comparable western populations (Craig *et al.* 1996). They have also been reported to have heavier personal BMI values. So it is possible that what is reported as a cultural difference is related to the physical differences between the cultures, since within a single cultural group (as reported here), people with a larger BMI preferred images of women with a larger BMI. Without correcting for the BMI of the observer, it may be impossible to determine whether differences in body-mass preferences between two populations are derived from cultural differences, or merely differences in the body-mass of the observers in the two groups.

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