

Original Article

Attractiveness of women's body: body mass index, waist–hip ratio, and their relative importance

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Body mass index and waist–hip ratio are related to human health and both play a role in mate choice. However, previous research is inconsistent as to what body mass index and waist–hip ratio values are preferred in women and what the relative importance of body mass index and waist–hip ratio for attractiveness is. Here, we made several methodological refinements to obtain reliable estimations. Participants (Poles) indicated the most attractive woman from a set of digitally manipulated high-quality silhouettes varying orthogonally in body mass index and waist–hip ratio and viewed from behind to exclude effects of the breast size. Then, each participant chose the more attractive silhouette from pairs in which one figure deviated from his/her ideal in body mass index and the other in waist–hip ratio. Both sexes preferred underweight women (body mass index = 17.3) with accentuated waist (waist–hip ratio = 0.66 for female and 0.70 for male judges). These represent preferences for unhealthy body mass and healthy body shape. Furthermore, body mass index proved twice as important for attractiveness as waist–hip ratio, even though literature data indicate that waist–hip ratio is at least as important for health as body mass index. We discuss the obtained pattern of preferences from the perspective of evolutionary psychology.

Key words: attractiveness, body mass index, mate choice, waist–hip ratio, women. [*Behav Ecol*]

INTRODUCTION

Physical attractiveness impacts heavily on human mating and non-mating behavior (Patzner 2006) and is more important in women than in men (Li and Kenrick 2006; Gottschall 2007). Body mass and body curvaceousness are 2 widely acknowledged determinants of women's physical attractiveness. Their importance is not limited to contemporary westernized populations (Tovée et al. 1999; Singh and Singh 2011) but extends to historical European and Asian societies as well as traditional cultures (Brown and Konner 1987; Singh and Singh 2011).

Body mass index

Although many tissues contribute to body mass, the amount of adipose tissue is especially strongly related to the body weight (Deurenberg et al. 1991). Among people of normal body mass, fat percentage in women is almost twice as high as in men (Deurenberg et al. 1991). The large quantity of adipose tissue in women constitutes a store of energy that can be utilized during food shortages or transferred to a child during pregnancy or lactation (Brown and

Konner 1987). Because the benefit of possessing such a store is proportional to the risk of food shortage, it was predicted that fatter women would be preferred by men in populations where the risk is high. Indeed, relatively heavy women are preferred in most small-scale societies (Brown and Konner 1987; Anderson et al. 1992; but see also Ember et al. 2005), by people of low socioeconomic status (Swami et al. 2010; see also references therein), and by hungry rather than satiated men (Swami and Tovée 2006).

Body mass in relation to height is commonly determined by body mass index (BMI), which is the weight in kilograms divided by the square of the height in meters (World Health Organization 2012). BMI values of between 18.5 and 25 are regarded normal (World Health Organization 2012). Underweight women (BMI < 18.5) are physically weak (Artero et al. 2010) and at high risk of developing osteoporosis (Coin et al. 2000), ovulatory dysfunction (Green et al. 1988), asthma, scoliosis, and intestinal conditions (Lusky et al. 1996). On the other hand, overweight (BMI > 25) and, especially, obesity (BMI > 30) in women is related to anovulatory cycles (Green et al. 1988), respiratory infections (Coetzee et al. 2009) and risk of developing cardiovascular diseases, type 2 diabetes, certain types of cancer, obstructive sleep apnea, osteoarthritis, and other diseases (Kopelman 2000). The association of BMI with mortality is J-shaped (Flegal et al. 2005), that is, the length of life is lower in obese people and, to a smaller degree, in underweight ones.

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Numerous studies that rely on assessments of women's photographs have shown that men in European, Asian, and Pacific cities regard slim but not underweight women as the most attractive (BMI = 19–21; Swami and Tovée 2007; see also references therein), although some studies have reported a preference for underweight women (Fan et al. 2004; Rilling et al. 2009; Brooks et al. 2010). Higher values of BMI (23–26) are preferred in nonurban populations worldwide (Swami and Tovée 2007; see also references therein). This means that men prefer women of medically normal BMI and have a dislike for both extremes. The preference for relatively low but not very low weight in women was also obtained in studies involving experimentally produced images of female silhouettes of various stoutness, such as line drawings (Fallon and Rozin 1985; Singh 1993; Schützwohl 2006; Swami et al. 2010) or digitally manipulated high-quality figures (Glauert et al. 2009; Gründl et al. 2009; Prantl and Gründl 2011; Tovée et al. 2012), although the precise BMI of those figures was unknown.

Waist-hip ratio

The most popular measure of female body curvaceousness is waist-hip ratio (WHR), that is, the ratio of waist girth to hip girth. Breast size, being another trait associated with curvaceousness, is a weaker determinant of attractiveness than WHR (Singh and Young 1995; Furnham et al. 1998; Dixon et al. 2011b) and will not be addressed here. In most human populations, WHR in young women averages 0.75–0.80 and increases with age; WHR in men is higher than in women by about 0.10–0.15 (Molarius et al. 1999). The low ratio of waist-to-hip size in females is a unique human feature (Singh 1993) and several adaptive mechanisms might have contributed to its evolution. Firstly, the human newborn has a relatively large head, and a large pelvis facilitates its delivery (Rosenberg 1992). Secondly, a narrow waist may indicate the absence of pregnancy and therefore current fecundity—a feature that ancestral men sought in women. This may be an especially important cue in humans because women do not signal their present fertility in any other easily perceptible way (Singh 1993). Thirdly, fat, when deposited around the hips rather than the waist, facilitates bipedal stability of pregnant and lactating women (Pawłowski and Grabarczyk 2003), contains fatty acids beneficial for brain development of the fetus and infant (Lassek and Gaulin 2008), and may dishonestly signal a broad pelvis and absence of pregnancy so as to make the woman attractive to men (Low et al. 1987; Furnham et al. 2004).

In contemporary human populations, WHR is negatively related to the level of estradiol, a female sex hormone, and positively related to the level of testosterone, a male sex hormone, which is why WHR is clearly lower in women than in men (see literature cited in Singh and Singh 2011). High WHR values in women are associated with mortality and many medical conditions such as cardiovascular diseases, type 2 diabetes, gallbladder disease, lung function impairment, carcinomas, menstrual irregularity, anovulatory cycles, and low fecundity (as reviewed in Singh and Singh 2011; World Health Organization 2011). According to sexual selection theory (Kokko et al. 2002), these would have driven the evolution of male preference for low-WHR women. Although preference for low WHR was indeed found in most studies on industrial and traditional societies (reviewed in Singh and Singh 2011), large inconsistency exists as to the most attractive value of WHR. Even if we limit our focus to populations of European descent, the value ranges from 0.5 (Heaney 2000; Schützwohl 2006), which is far below the normal range of the trait, to 0.8, which is somewhat above the average (Henss 1995), or even higher values (Furnham et al. 2006).

The cross-cultural, historical, and intrapopulation variation, that has been found for the most attractive value of WHR, raised a claim that the preference is a cultural rather than an evolutionary construct (Swami et al. 2009; but see Cashdan 2008).

Large inconsistencies also exist with regard to the relative importance of body mass (as measured with BMI) and curvaceousness (as determined by WHR) for women's attractiveness. Some research has indicated BMI as being of much greater importance and that the role of WHR is minor (Tovée et al. 1999; Streeter and McBurney 2003; Fan et al. 2004; Smith et al. 2007; Rilling et al. 2009), whereas other authors have found WHR to be the more important parameter (Singh 1993; Singh and Randall 2007; Gründl et al. 2009; Brooks et al. 2010; Dixon et al. 2010). Similar divergence exists as to which parameter of the observed female bodies exerts a stronger impact on the reward system in the observer's brain: WHR (Platek and Singh 2010) or BMI (Holliday et al. 2011).

Limitations of previous research

The chief reason for above-mentioned inconsistencies seems to be methodological diversity, and, in particular, the stimuli to be assessed. These include schematic drawings of females varying in BMI and WHR (Fallon and Rozin 1985; Singh 1993), digitally manipulated images (Rozmus-Wrzesińska and Pawłowski 2005; Donohoe et al. 2009), nonmanipulated photographs of real women (Thornhill and Grammer 1999; Tovée et al. 1999), movies with rotating 3D figures (Fan et al. 2004; Rilling et al. 2009), and pairs of photographs of the same woman before and after a surgical WHR reduction (Singh and Randall 2007; Dixon et al. 2010). In studies based on nonmanipulated images of real women, estimation of the preferred BMI and WHR values is difficult because attractiveness assessments are confounded by an BMI-WHR intercorrelation as well as other body characteristics correlated with these indices (Tassinari and Hansen 1998; Tovée et al. 1999; Rilling et al. 2009). For example, Rilling et al. (2009) observed a strong bivariate correlation between BMI and attractiveness of female body ($r = -0.50$), yet BMI was not a significant predictor of attractiveness in analyses of multiple regression, whereas traits like waist girth and leg length were. Studies involving photographs of women before and after surgical WHR reduction can determine which of these 2 is the more attractive but does not reveal the most attractive possible value of WHR. These studies are also unable to compare the relative importance of BMI and WHR for attractiveness because those surgical operations altered WHR to a much greater degree than BMI (Singh and Randall 2007).

Digital manipulation of silhouettes can potentially be the best approach, yet previous studies of this sort embodied several serious methodological weaknesses. Firstly, many of these studies used schematic silhouette drawings developed by Singh (1993) or Tassinari and Hansen (1998), which were extensively criticized for their poor realism and therefore unreliable results (Tovée et al. 1999; Rilling et al. 2009). Secondly, previous methods for digital manipulation of WHR usually altered waist width or hip width alone (but see Kościński 2012), which caused simultaneous change of the figure's BMI. This makes it impossible to establish the individual role of BMI and WHR in determining the attractiveness of such silhouettes (Tovée et al. 1999; Rilling et al. 2009). Thirdly, the manipulation of BMI in many studies also altered breast size (Fallon and Rozin 1985; Glauert et al. 2009; Swami et al. 2010), making it impossible to conclude whether the thinnest women were not preferred because their BMI was too low or their breasts

too small. Fourthly, the WHR of the prepared silhouettes was usually calculated as the ratio between *width* of waist and hips on 2D images, whereas the appropriate method is to determine the ratio between their *circumferences* (Rilling et al. 2009; World Health Organization 2011). Kościński (unpublished data) determined that width-based WHR underestimates the true, circumference-based WHR by 0.04, which is about 1 standard deviation (SD).

Another limitation of previous research on the relative importance of BMI and WHR for attractiveness is that statistical analyses were conducted on silhouettes' assessments being averaged across all raters. This may underestimate the importance of the predictor whose attractiveness is perceived more variously among the judges. If, for example, one person highly assesses a silhouette with WHR of 0.7 and lowly assesses a silhouette with WHR of 0.8, whereas another has the opposite preferences, then the averaging of ratings by both these judges would result in equal attractiveness of both silhouettes. The obtrusive conclusion that WHR, therefore, does not influence attractiveness would be erroneous because WHR strongly influenced the judgement of each of the 2 raters.

Present study

In the present study, we attempted to determine the most preferred BMI and WHR values and the relative importance of these traits for attractiveness of women's bodies by using stimuli free of the above-mentioned weaknesses. Stimulus images were made on the basis of a photograph of a woman possessing body proportions typical for local (Polish) females. Relying on anthropometric data for the 3D shape of the female body, we manufactured rear-view silhouettes representing women of specific BMI and WHR values, where these parameters were manipulated orthogonally. The silhouettes were presented to judges from behind so as to exclude the confounding effects of the face and breast appearance on attractiveness perception. For each 2D female silhouette, circumference-based rather than width-based WHR was estimated.

The relative importance of BMI and WHR was investigated for each individual participant. First, the participant identified the most attractive, in his/her opinion, silhouette in a set of female figures diversified orthogonally in BMI and WHR. Then, the participant was presented with pairs of silhouettes such that one silhouette in each pair departed from the most attractive silhouette in BMI only, whereas the other departed from it in WHR. We reasoned that a deviation from the ideal silhouette in the trait more important for women's attractiveness would impair attractiveness to a greater degree than an equivalent deviation in the other trait. Thus, if BMI is more important in determining women's attractiveness than WHR, participants would be expected to choose silhouettes departing from the ideal in WHR as more attractive than silhouettes deviating from the ideal in BMI. Alternatively, if WHR is more important than BMI, the opposite choices were expected.

The theory of sexual selection predicts that preferences evolve to facilitate selection of a partner of high mate value (Kokko et al. 2002). Health in a broad sense is one of the most important components of mate value (Buss 1999) and is related to the individual's BMI and WHR (see above). We, therefore, predict that people should perceive women with low, but not very low, BMI and WHR as the most attractive because these values signal optimal health. Literature data also indicate that WHR in humans is at least as important for health and survival as BMI (Singh and Singh 2011; World Health Organization 2011). In light of this, we expect participants to value WHR to no less a degree than BMI when judging attractiveness.

METHODS

Construction of stimuli

Twenty-two young white Polish women (aged 18–28) of apparent normal physique were photographed from the back and the right profile at a distance of 3 m with a digital camera (Panasonic DMC-FZ18, 8.1MPx). They were clothed in only their underwear or a bikini. The women reported their height and weight, and their waist and hip circumferences were measured. Waist circumference was taken at the level of the smallest body width between ribs and hips and hip circumference at the level of the maximum body width below the waist. Neither WHR (range = 0.65–0.81, $M = 0.75$, $SD = 0.05$) nor BMI (range = 17.5–24.9, $M = 20.6$, $SD = 2.3$) was related to the women's age ($r = 0.26$ and -0.03 , both P s > 0.2).

Six of the women with apparently typical physique were measured for a further set of anthropometric traits and compared with average values for Polish women (for details, see Kościński 2012). In this way, the woman possessing body proportions closest to the population means was identified. She was 22 years old, 167.5 cm tall, 53.5 kg in mass, and had a BMI of 19.1 and a WHR of 0.70. Although she had somewhat lower body mass and WHR than the appropriate population averages (58.7 kg and 0.72), these parameters were manipulated in her photograph during the stage of production of the final stimuli. In the rear-view photograph of this woman, the left body side was reflected and superimposed on the right to achieve an ideally symmetric figure. The legs were digitally lengthened by an equivalent of 1.7 cm at the expense of trunk length so as to make the relative leg length equal to the population average (this was accomplished by the method of warping; see below for details). The shoulder width, chest width, and upper limb length of the woman required no alteration.

The obtained silhouette representing the average body proportions for Polish women was further modified to produce figures of differing BMI and WHR values. Although a change in BMI that does not impact on WHR can be easily achieved by an appropriate change in overall body width, the modification of a rear-view female silhouette for WHR without producing a change in the BMI of the depicted woman is more challenging and requires a simultaneous change in both waist and hip width (Figure S1). Because we did not manipulate the silhouettes' height, the invariance of BMI requires invariance in body mass, which can be approximated by body volume. The influence of waist and hip manipulations was restricted to the breast–knee part of the body (Figures S1 and S2); further analysis was therefore confined to this region only.

We modeled the breast–knee region of the female body as an orderly vertical pile of 99 cylinders with irregular bases as obtained by horizontal sections of this region at 100 levels (Figure S2) and determined how the size and shape of this region in a rear-view silhouette translates to the volume (and weight) of this body part. To this end, ratios between anteroposterior and transverse body dimensions (depth-to-width ratios) at 100 levels between breasts and knees for all 22 photographed women were calculated by dividing body widths (in pixels) on the profile-view image by the corresponding body widths on the rear-view image. These depth-to-width ratios tended to depend on women's BMI, for example, the correlation was $r = 0.44$ ($P = 0.04$) for the level of narrowest waist, $r = 0.57$ ($P = 0.006$) for the most protruding buttocks, and $r = 0.35$ ($P = 0.11$) at the crotch level. Regression analyses of the depth-to-width ratio on BMI were then performed for a total of 100 levels between the breasts and knees and the results used to

estimate depth-to-width ratios for the subsequently constructed silhouettes of varying BMI values.

To determine the shape of the base of the cylinders constituting the model of the body, horizontal body sections were produced with Bryce 7 software on a popular 3D digital model of an anatomically correct woman named Victoria (www.daz3d.com). These sections were made at 5 levels: just below breasts, at the level of narrowest waist, greatest protrusion of the buttocks, crotch, and knees, with the superior views of the sections being saved to JPG files. The ratio between the area of each body section and the area of the rectangle circumscribed around this section (i.e., the percentage of body pixels in this rectangle) was then determined. Ratios for the remaining body levels were obtained by linear interpolation.

The above-mentioned data enabled estimation of the antero-posterior dimensions and body volume between the breasts and knees for any rear-view silhouette. The total volume was the sum of the volumes of 99 cylinders with irregular bases. The volume of each cylinder was the product of its height and the area of its base. The height of the cylinder was taken as the height of the body part embracing the cylinder (e.g., hip–knee segment) divided by the number of cylinders in the body part (the breast–waist, waist–buttocks, buttocks–crotch, and crotch–knees segments comprised 20, 30, 10, and 39 cylinders, respectively). The area of the base was the product of 3 parameters: body width, body depth, and the percentage of body area on the section at the appropriate level (more precisely, the parameters for a cylinder's base were averages of these taken for 2 adjacent levels).

All calculations of digital manipulations to be applied to the silhouette images were performed in the Microsoft Excel application. First, we determined the percentage changes in overall body width (excluding head) to be applied to the initial silhouette (BMI = 19.1) in order to produce 12 silhouettes representing women with BMI of 15.0–26.0 by 1.0. A straightforward reasoning is that a change of X percent in body width corresponds, in real individuals, with the same X percent change in body depth, which results in body weight being $(1 + X/100)^2$ of the original weight [note that Wilson et al. (2005) incorrectly changed the width of the silhouette by X percent to alter its BMI by X percent]. We essentially followed this reasoning but added a minor correction reflecting the fact that depth-to-width body ratios were not constant as body size varied (see above). The range of BMI from 15 to 26 embraces figures from severely underweight to mildly overweight (World Health Organization 2012) and includes the values found as the most attractive in previous studies (see Introduction).

Each of the thus produced 12 silhouettes was further modified in WHR value. Waist girth and hip girth, the ratio of which constitutes WHR, were estimated for each silhouette using the method devised and validated by Kościński (unpublished data). Briefly, the waist circumference of the woman depicted in a rear-view silhouette was calculated as the perimeter of the ellipse determined by the width and depth of the woman's body at the level of narrowest waist. Body shape of the section at widest hips was not elliptic, and therefore, the hip circumference was estimated with a carefully constructed combination of elliptic and line segments (Figure S2).

The Solver add-in for the Microsoft Excel application was used to determine the magnitude of waist and hip width changes required to obtain a silhouette depicting a woman who possessed the desired WHR and whose BMI was equal to the BMI of the original silhouette. This was facilitated by spreadsheet formulas that calculated anteroposterior body dimensions, the volume of the breast–knee segment, and waist and hip circumference on the basis of data on body widths of a rear-view female silhouette. For

each of the previously determined 12 silhouettes varying in BMI, the Solver was run 26 times so as to obtain silhouettes possessing WHR from 0.60 to 0.85 by 0.01. This range covered the normal WHR variability in young Polish women, which is about 0.64–0.85 (Pawłowski and Grabarczyk 2003; Jasieńska et al. 2004), and also included some lower values so as to test whether the most attractive WHR falls below the normal range as was suggested in some studies (Heaney 2000; Schützwohl 2006).

The magnitude of changes in overall body width (to alter BMI) and in waist and hip width (to alter WHR) as determined in Microsoft Excel was then graphically applied to images of rear-view silhouettes using author-developed software (in Microsoft Visual Basic 6). Images were manipulated by means of warping (Figure S1), a common technique for image distortion used in many studies on attractiveness of faces (e.g., Perrett et al. 1994) and silhouettes (e.g., Kościński 2012). The resultant images were saved to JPG files (Figure 1). These comprised 312 images embracing 12 levels of BMI (from 15 to 26) times 26 levels of WHR (from 0.60 to 0.85).

Validation of stimuli

The method of manipulation of WHR applied in this study has been validated in Kościński (unpublished data) so we checked for the credibility of the method of BMI manipulation only. Six silhouettes of typical WHR (0.72) and BMI of 15, 17, 19, 21, 23, and 25 were selected from our set and placed individually in the center of a board. In addition, 10 photographs of real women of known BMI and highly diversified in this trait were taken from Swami, Salem, et al. (2008) and distributed peripherally on the board from the thinnest to the heaviest with labels from 1 to 10 attached to them. The 6 boards were projected in random order on a wall and 19 men and 19 women (aged 23–40) were each requested to indicate the women from the reference set having the same body mass as the woman in the center of the board. Evaluations were done on a printed analog scale with labels from 1 to 10 anchored to it; adjudications between the real women were thus allowed. The images from Swami and coworkers differed in many ways from ours—among others, they were clothed in a leotard and leggings, depicted in a grayscale against a black background, shown from the front with their limbs markedly shifted to the sides, differed from each other in body shape, breast size, and height on the image, and some of them were noticeably asymmetric. The use of their stimuli constituted, therefore, a stringent test for our stimuli by preventing a simple matching of the figures by body width.

The judges' answers were read out from their scales and averaged for each silhouette. Relying on the BMI values provided by Swami and coworkers for reference silhouettes, we calculated the expected answers for each of our women as well as the BMI values corresponding with the actual answers (Figure S3). The judged BMI values correlated with the intended BMI at 0.995 (across 6 examined silhouettes). The difference between judged and intended BMI values was 0.42, −0.27, −0.50, −2.24, −2.19, and −2.39 for silhouettes with the intended BMI of 15, 17, 19, 21, 23, and 25, respectively; and these values correspond with 1.14, −0.73, −1.36, −6.11, −5.95, and −6.49 kg of body mass in a woman of a typical stature (165 cm). This indicates excellent accuracy for BMI values between 15 and 19 and an underestimation for values between 21 and 25. The underestimation may be a result of any of the above-mentioned differences between our stimuli and those by Swami and coworkers. In addition, some variation in body mass among reference silhouettes can be related to factors that do not influence appearance, such as

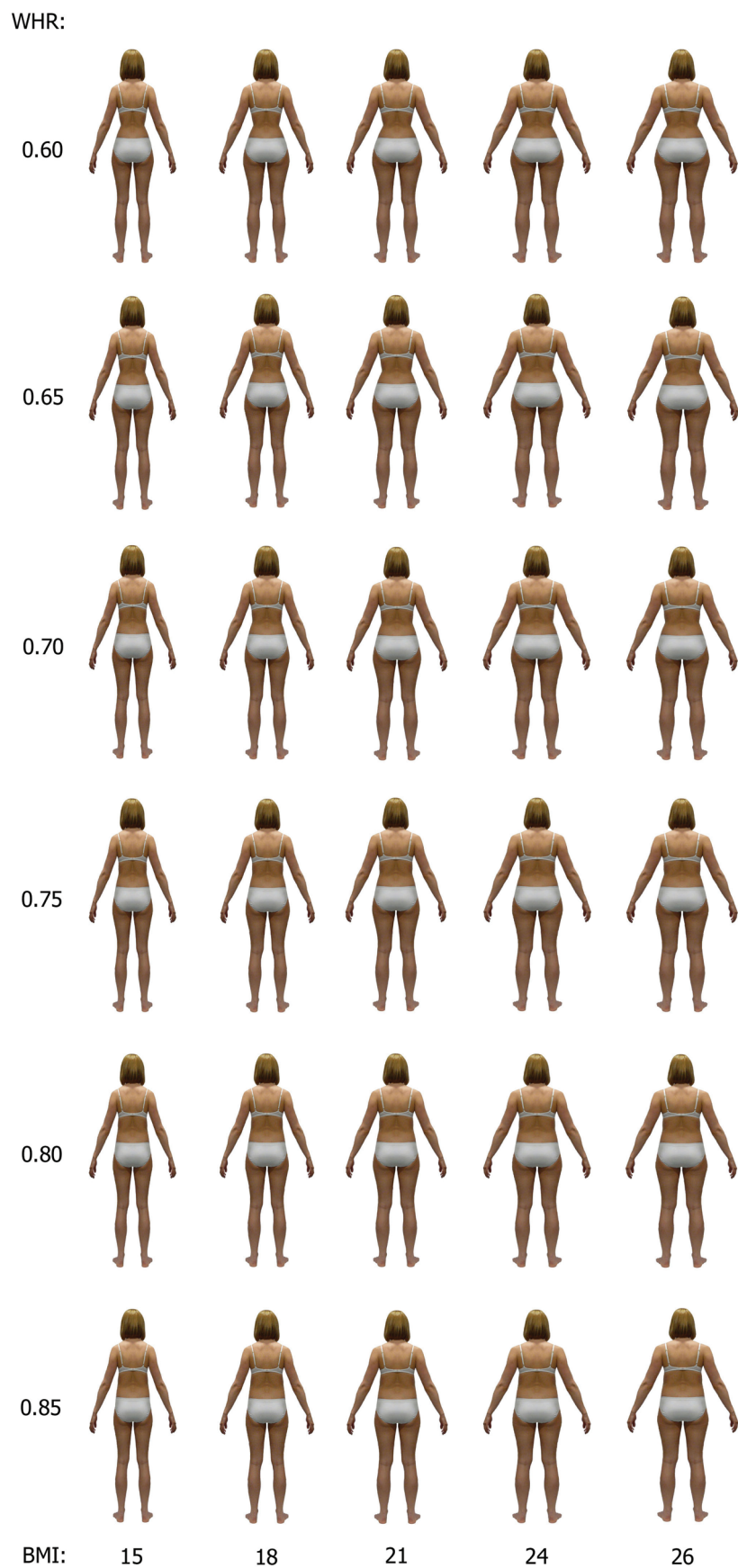


Figure 1

Examples of stimulus silhouettes. Altogether, 312 images were constructed and they comprised 12 levels of BMI (from 15 to 26) times 26 levels of WHR (from 0.60 to 0.85).

bone density. For example, figures no. 6 and 7 possess similar widths of trunk and legs but the latter had a BMI value higher by almost 4 units which corresponds to about 10 kg of body mass provided the height remains constant (Swami, Salem, et al. 2008).

An analysis of variance with the intended BMI as a repeated variable and sex as a categorical variable revealed a significant effect of sex ($F_{1,36} = 7.43$, $P = 0.010$); men chose lighter silhouettes and thereby underestimated the body mass of assessed women to higher degree than women (Figure S3). Higher accuracy of women than men in assessing female body mass was already reported by Vartanian et al. (2004) and may be related to the fact that women often assess the weight of other women in their everyday lives (Jones 2001). We, therefore, asked 18 additional women (all 24 years old) to estimate body mass of 2 female silhouettes: one having BMI of 17 and WHR of 0.68 (i.e., the most attractive figure according to the participants in the main study; see below) and the other having the typical body proportions of young Polish women (BMI = 21, WHR = 0.75). The participants were informed that the depicted women were of average height (165 cm). The mean estimated body mass for these silhouettes ($\pm$ SD) was 48.8 ± 2.8 and 60.5 ± 6.3 kg, respectively, corresponding to BMI values of 17.9 and 22.2 and indicating a slight overestimation by 2.5 and 3.3 kg.

Attractiveness judgements

Sixty-nine women (aged 18–31, $M = 23.8$) and 52 men (aged 18–40, $M = 24.9$) from Poznań (a relatively large city in Western Poland) participated in the study. They were each given a web page address and asked to complete the questionnaire therein. The questionnaire interface was developed in Macromedia Flash MX 6. First, participants provided their age, height, body mass, and sexual orientation (from 1—definitely homosexual to 5—definitely heterosexual; answer refusal being allowed). Two women who described themselves as bisexual and 1 man who refused to provide his sexuality were excluded from further analysis, thus reducing the sample size to 67 females and 51 males, all heterosexual.

Next, a board that aimed to determine the most attractive woman's figure according to the participant was displayed on a screen. A female silhouette of resolution 320×637 pixels was displayed on the left-hand side of the screen, whereas a rectangle enclosing a disk and an instruction to use the disk so as to make the silhouette as attractive as possible were shown on the right-hand side of the screen (Figure 2). The disk could be moved with the computer mouse to any location within the rectangle. The location of the disk in the rectangle translated into BMI and WHR values of the silhouette displayed on the left-hand side of the screen. The left, right, bottom, and top edge of the rectangle corresponded to the lowest BMI (15), highest BMI (26), lowest WHR (0.60), and highest WHR (0.85), respectively. The initial position of the disk was randomly set to 1 of 4 angles of the rectangle. As the participant moved the disk, the silhouettes were correspondingly replaced by others giving the impression that the body of the depicted woman had changed in size and/or shape. In this way, the participant chose the most attractive silhouette and then clicked the "OK" button.

A second board then appeared on the screen. The aim of this was to determine the relative importance of BMI and WHR for women's attractiveness. Each participant was presented with pairs of silhouettes in which one silhouette of each pair departed from the participant's ideal silhouette in BMI only, whereas the other departed from the ideal in WHR. The changes made to BMI were by 2, 4, and 6 units and to WHR by 0.03, 0.06, and 0.09 units

(Figure 2). Because SDs of BMI and WHR in young Polish women amount to 3.2 and 0.05, respectively (Pokrywka et al. 2006), the applied changes approximated to 0.625, 1.25, and 1.875 SDs of BMI and 0.6, 1.2, and 1.8 SDs of WHR. This means that the silhouettes selected for the pairwise presentation varied similarly in BMI and WHR in terms of naturally occurring variation in each trait. The direction of the departure from the ideal silhouette was always toward the mean value of the respective trait. For example, if a participant selected a silhouette of below-average BMI and above-average WHR as the most attractive, he/she was subsequently presented with silhouettes of greater BMI and lower WHR as compared with the ideal silhouette (Figure 2).

Each silhouette departing from the ideal in BMI was paired with each silhouette deviating in WHR, making 9 pairs altogether. If we denote the silhouettes departing progressively from the ideal in BMI and WHR as BMI1, BMI2, BMI3, WHR1, WHR2, and WHR3, these pairs were then BMI1–WHR1, BMI1–WHR2, BMI1–WHR3, BMI2–WHR1, BMI2–WHR2, BMI2–WHR3, BMI3–WHR1, BMI3–WHR2, and BMI3–WHR3. The order of presentation of the pairs was randomly varied between the participants. The location of silhouettes constituting each pair on the left- and right-hand side of the screen was also randomized in each instance. Each participant was asked to mouse-click the more attractive silhouette in each pair. After the mouse-clicking, both silhouettes disappeared, a fixation cross appeared in the center of the screen for 1 s, and then another pair of silhouettes was presented for evaluation. As explained above, a systematic tendency to choose a silhouette departing from the ideal in one trait would indicate that the other trait is more important for attractiveness of female body.

Statistical analyses were conducted using Statistica StatSoft 8.0 and reported P levels are 2-tailed. The study was approved by

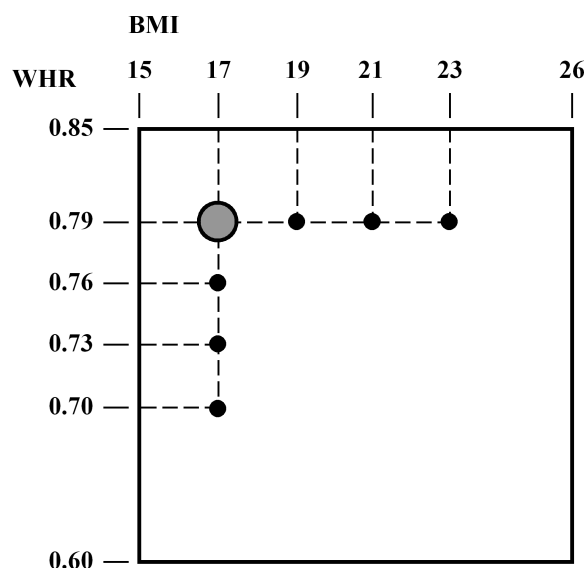


Figure 2

Each participant moved the disk within the rectangle with the computer mouse so as to find, in his/her opinion, the most attractive woman's figure in regard to BMI and WHR. On the basis of this ideal silhouette, 6 silhouettes were selected for investigation of the relative importance of BMI and WHR for attractiveness. These silhouettes differed from the ideal by 2, 4, and 6 units of BMI and by 0.03, 0.06, and 0.09 units of WHR. The example depicts the selection of the silhouette possessing BMI of 17 and WHR of 0.79.

the Institutional Review Board at Poznan University of Medical Sciences (726/11).

RESULTS

Preference for BMI and WHR

Figure 3 depicts the distribution of ideal BMI and ideal WHR, that is, the BMI and WHR values of the silhouette chosen as the most attractive. The mean for the ideal BMI was 17.34 (SD = 2.42, SE = 0.30) according to the women judges and 17.29 (SD = 2.10, SE = 0.29) when judged by men, whereas the mean for the ideal WHR was 0.665 (SD = 0.044, SE = 0.005) for the women and 0.705 (SD = 0.060, SE = 0.008) for the men. As seen in Figure 3, the preference for BMI was highly skewed and the minimal value of 15 was clearly the most frequently chosen as the most attractive by judges of either sex. The preference for BMI was not related to the judges' sex (Mann–Whitney U test [further, M–W test]: $U = 1678$, $Z = -0.17$, $P = 0.868$), but women preferred a significantly lower WHR than men (M–W test: $U = 1040.5$, $Z = -3.63$, $P < 0.001$). Two women selected BMI above 24 as the most attractive and the Grubbs' test regarded these choices as outliers, yet their omission from analysis did not alter the conclusion regarding the independence of BMI preference from sex (new mean for women = 17.09; M–W test: $U = 1576$, $Z = -0.45$, $P = 0.650$). Men were more diversified in their selection of the ideal WHR than women (Levene's test: $F_{1,116} = 5.07$, $P = 0.026$).

To determine whether the ideal BMI and ideal WHR depended on the BMI and WHR values of the silhouette that was initially displayed on the screen, a MANOVA was carried out with the ideal BMI and ideal WHR as dependent variables, and sex, initial BMI (low/high), and initial WHR (low/high) as independent

variables. The model was significant for the ideal BMI ($F_{7,110} = 3.40$, $P = 0.003$) and ideal WHR ($F_{7,110} = 2.63$, $P = 0.015$). The ideal WHR was predicted only by sex ($F_{1,110} = 16.31$, $P < 0.001$), conforming with the above-mentioned result showing that women preferred a lower WHR than men. The ideal BMI was predicted by initial BMI ($F_{1,110} = 5.31$, $P = 0.023$) and the interaction between sex and initial WHR ($F_{1,110} = 7.59$, $P = 0.007$). The Tukey's test indicated that the ideal BMI was higher when the initial BMI was high than low ($M = 17.86$ and 16.73 , respectively, $P = 0.006$), and, for female judges only, it was higher when the initial WHR was low than high (women: $M = 18.03$ and 16.59 , respectively, $P = 0.040$; men: $M = 16.75$ and 17.78 , respectively, $P = 0.344$). Although analysis of variance is robust to violations of the normality assumption (Ferguson and Takane 1989), we endeavored to confirm these effects for the highly skewed and nonnormally distributed ideal BMI (Kolmogorov–Smirnov test: $d = 0.159$, $P < 0.01$) by using nonparametric tests. The M–W test confirmed that the ideal BMI depended on initial BMI ($U = 1239$, $Z = -2.68$, $P = 0.007$) and on initial WHR for women ($U = 390.5$, $Z = -2.13$, $P = 0.033$) but not men ($U = 232.5$, $Z = 1.73$, $P = 0.084$).

The ideal BMI and WHR were unrelated to the age, height, weight, and BMI of the participating women and men (all Spearman's $|R_s| < 0.21$, all $P_s > 0.08$).

Relative importance of BMI and WHR

Neither a judge's sex nor the side of presentation of a silhouette on the screen influenced the choice of the more attractive silhouette for any of the 9 pairs (all $P_s > 0.06$ according to the Fisher's Exact test). The M–W test indicated that the order of presentation of a silhouette pair was associated with the judges' choices for 2 pairs: BMI1–WHR1 ($U = 1207.5$, $Z = 2.59$, $P = 0.010$)

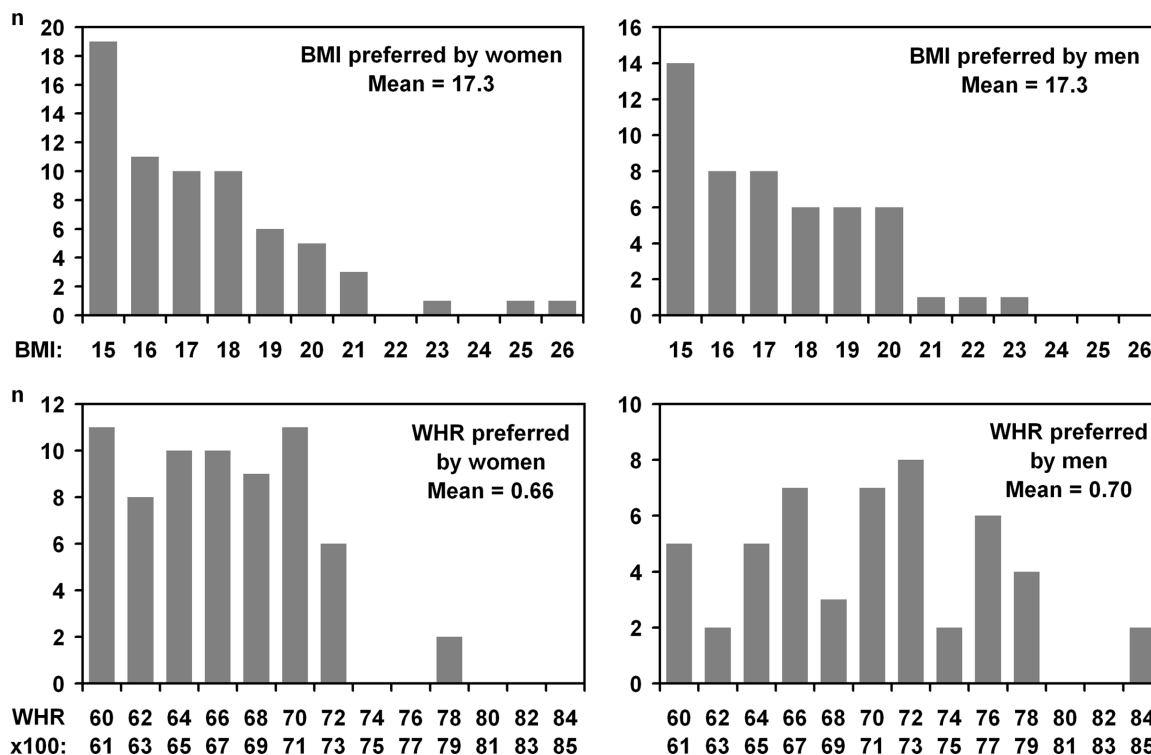


Figure 3

Distribution of BMI and WHR in silhouettes indicated as the most attractive by female ($n = 67$) and male ($n = 51$) participants. Values of WHR on x axes have been multiplied by 100.

and BMI3–WHR1 ($U = 286$, $Z = 2.45$, $P = 0.014$); these effects, however, did not survive the Bonferroni correction (both P s $> 0.05/9 = 0.0056$). We, therefore, collapsed the choices made by participants of both sexes and in subsequent analyses did not control for the side of presentation of silhouettes on the screen or the order of presentation.

Figure 4 shows the frequency of choice of the WHR-manipulated rather than BMI-manipulated silhouette for each silhouette pair (i.e., the silhouette deviating from the participant's ideal in WHR rather than BMI). If BMI and WHR were equally important for attractiveness, the BMI-manipulated and WHR-manipulated silhouette should have been of equivalent attractiveness in pairs BMI1–WHR1, BMI2–WHR2, and BMI3–WHR3 (the degree of BMI and WHR manipulation was comparable for these pairs only). If so, the choice of the more attractive silhouette would have been random for these pairs, and the expected frequency of choice equal to 0.5 for each silhouette in a pair. Empirical frequencies of choice of the WHR-manipulated silhouette were found to be well above the expected value: 59% for BMI1–WHR1, 71% for BMI2–WHR2, and 79% for BMI3–WHR3. According to the binomial test, the P level for the hypothesis of random choice was 0.053 for BMI1–WHR1 and below 0.001 for BMI2–WHR2 and BMI3–WHR3. The deviation from the ideal in BMI was, therefore, more detrimental to attractiveness than an equivalent deviation in WHR, meaning that BMI was more important for female attractiveness than WHR.

For the pairs of silhouettes subjected to a greater manipulation in BMI than WHR, the WHR-manipulated silhouette was chosen in more than 80% of cases (Figure 4) and all P levels in the binomial test were below 0.001. For the pair of BMI1–WHR2 (where WHR was manipulated twice as much as BMI), the frequency was 49% ($P = 0.927$), indicating a random choice, and for the pair of BMI1–WHR3 (WHR manipulated 3 times as much as BMI), the frequency was only 34% ($P < 0.001$). Taken together, all the results suggest that BMI is twice as important as WHR for the attractiveness of the female body.

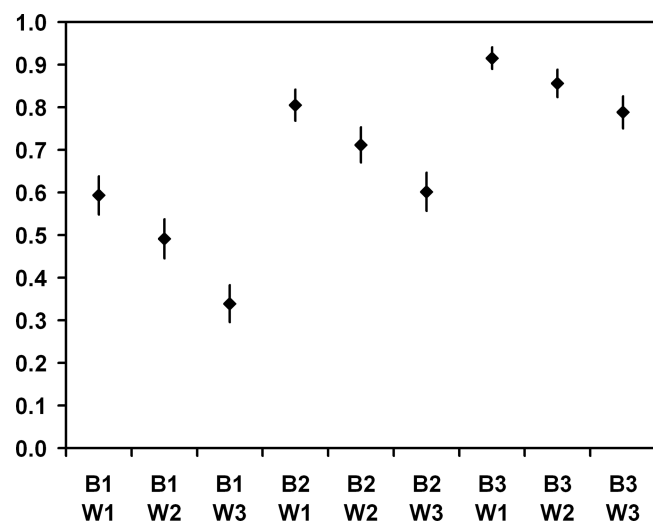


Figure 4

Frequency of choice ($\pm$ standard error) of the silhouette manipulated in WHR as the more attractive in pairs where one silhouette departed from the participant's ideal female body in BMI and the other in WHR. B1, B2, B3, W1, W2, and W3 denote figures deviating from the ideal by 1, 2, or 3 steps in BMI or WHR, respectively (see Figure 3); each step approximating to 0.6 of SD for each trait.

The frequencies for BMI1–WHR1, BMI2–WHR2, and BMI3–WHR3 pairs suggest that the predominance of BMI over WHR in determining attractiveness increased with the degree of manipulation. This was confirmed by the McNemar's test: the choice frequency of the WHR-manipulated silhouette increased significantly between BMI1–WHR1 and BMI2–WHR2 ($\chi^2_1 = 6.04$, $P = 0.014$) and between BMI1–WHR1 and BMI3–WHR3 ($\chi^2_1 = 13.83$, $P < 0.001$), and marginally significantly between BMI2–WHR2 and BMI3–WHR3 ($\chi^2_1 = 3.37$, $P = 0.066$).

DISCUSSION

Preference for WHR

We found that the most attractive value of WHR in women averaged 0.705 as adjudged by men and 0.665 for women, which are below-average values for WHR but not extremely so. This agrees with most studies on the attractiveness of WHR (reviewed in Singh and Singh 2011). This result also supports the claim that people prefer those values of WHR, which cue for good health of a women (i.e., relatively low values) and that the preference is an evolutionary adaptation for seeking a suitable partner (see Introduction).

In the present study, women preferred significantly lower WHR than men, which suggests that women put a higher premium on small waist versus small hips compared with men. Although some studies found no sex difference in the preferred female WHR (see literature cited in Singh and Singh 2011), some others, in accordance with our finding, reported a preference by women for a smaller waist than men (Harrison 2003; Prantl and Gründl 2011). We also observed that men were more diversified in their preferences for WHR than women. These sex differences dovetail with findings by Cornelissen et al. (2009) that women are more efficient in their visual inspection of the waist–hip contour of the female body than men, and in attractiveness assessments, they gaze at the waist region more frequently and rely on WHR more strongly.

Women are expected to perceive the physical attractiveness of other females in a similar way to men so as to assess the mate value of competitors and to adjust their own mating and rivaling behaviors (Dijkstra and Buunk 2001; Brewer et al. 2007). However, because men rather than women choose females as sexual or romantic partners, it is expected that men should pay at least as much attention as women to cues for female mate value (including WHR). One may speculate that the emphasis placed by women on the waist area is important to their assessment of other women not only as mating rivals but also as social allies or friends (Thornhill and Grammer 1999; Bleske-Rechek and Lighthall 2010). It is also possible that they follow the dictates of the women's media, which constantly highlight the importance of a smaller waist for good health and look (Harrison 2003). Further investigation is warranted for sex differences in perception of the waist and hip region.

Preference for BMI

Although the most preferred values of WHR in the present study were in line with those of previous research, the observed preference for the BMI was unexpected. Although previous studies usually reported a preference for BMI values within the medical norm of 18.5–25 (see Introduction), participants in the present study preferred, on average, a BMI of 17.3 and most frequently chose the silhouette with BMI of 15, which is regarded as severely underweight (World Health Organization 2012). The preference was independent of the raters' sex, as is the case in most previous

research (Furnham et al. 1998; Tassinari and Hansen 1998; Prantl and Gründl 2011; Tovée et al. 2012; but see Fallon and Rozin 1985).

Validation tests of stimuli used in this study proved the accurate perception of body weight for silhouettes with the intended BMI of 15, 17, and 19, and therefore the preference for underweight women obtained did not result from a fault in stimuli production or biased perception. It is also unlikely that Poles would have a particularly strong preference for slim bodies because attractiveness assessments by Poles in a study that used female line drawings (Swami, Rozmus-Wrzesinska, et al. 2008) were similar to participants from other countries. The incompatibility between the presently obtained preference for underweight women and the previously reported preference for women of normal weight may be due to methodological weaknesses in the previous studies. Many of these studies involved line drawings of female silhouettes or digitally manipulated high-quality images, in which the precise BMI could not be determined or the body mass manipulation was confounded by breast size variation (see Introduction for references). Many other studies relied on photographs of real women, which differed uncontrollably from one another in many features potentially influencing the attractiveness ratings. These studies used fitting procedures to determine the most attractive value of BMI. For example, Tovée et al. (1999) fitted a third degree polynomial and obtained the most attractive BMI as being between 19 and 20. However, a visual inspection of their empirical data suggests BMI values of 16–19 (i.e., underweight) to be the most attractive (see Figure 2a in their paper). The problem crops up repeatedly in many of the studies by Martin Tovée, Viren Swami, and colleagues (see Swami and Tovée 2007, and references therein). Yet, on the other hand, we stress that some studies based on images of real women did find a monotonic negative relationship between BMI and attractiveness, and women who possessed the lowest BMI (even below 16) obtained the highest ratings (Fan et al. 2004; Rilling et al. 2009; Brooks et al. 2010). The present study is, to the best of our knowledge, the first that allowed participants to choose the most attractive silhouette from among a set of female images that were stringently manipulated in their stoutness (with no confounding variation in, e.g., breast size), and the BMI of the depicted women was carefully determined and externally validated. We, therefore, believe the presently obtained preference for underweight women is credible. On the other hand, because breast size is strongly related to the woman's body mass and BMI (Manning et al. 1997; Wade et al. 2010), and small breasts are regarded as minimally attractive (Dixon et al. 2011a; Zelazniewicz and Pawlowski 2011), many underweight women in the real world may not seem beautiful to men due to their small breasts.

We observed that the BMI of the initially presented silhouette positively impacted on the BMI of the silhouette subsequently chosen as being the most attractive. Such dependence of preferences on previously seen stimuli, or visual adaptation, has repeatedly been observed for faces (see references in Little et al. 2011) and bodies (Glauert et al. 2009; Kościński 2012). The initial WHR, however, did not influence the subsequently chosen ideal WHR, which may suggest that people pay less attention to WHR of the seen woman than her BMI. Interestingly, the initial WHR negatively impacted on the ideal BMI, but only for female judges. This suggests that high WHR (wide waist) gave the impression of a larger body mass to female participants who then compensated for this by lowering

the BMI. If so, it would again affirm the evidence that women pay more attention to the waist than men.

From the perspective of sexual selection theory, it is surprising that severely underweight women, who are at elevated risk of many medical problems and shorter life duration (see Introduction), are regarded the most attractive. However, such preference may be a manifestation of an adaptive mating rule to prefer stoutness proportional to the risk of food shortage. In accordance with this rule, relatively heavy women are preferred in most small-scale societies (Brown and Konner 1987; Anderson et al. 1992; but see also Ember et al. 2005), in groups of low socioeconomic status (Swami et al. 2010; see also references therein), and by hungry rather than satiated men (Swami and Tovée 2006). In contemporary developed countries, the food accessibility is at a level unprecedented in the evolutionary past, and this shifts the preference to very slender, albeit unhealthy, women. This would seem, therefore, to be an example of a supernormal response to a supernormal stimulus (Staddon 1975), where the stimulus is the food availability and the response is the preference for slenderness. This is also an example of an evolutionary trap, in which rapid environmental changes result in adaptive decision rules producing maladaptive behaviors (Schlaepfer et al. 2002).

Relative importance of BMI and WHR

Previous research is highly inconsistent about the relative importance of BMI and WHR for attractiveness of women's body but the methods that were applied were flawed (see Introduction). In the present study, a novel approach was adopted: Each judge indicated the silhouette that he/she subjectively perceived as the most attractive in respect of BMI and WHR values and then chose the more attractive silhouette from pairs in which one figure deviated from his/her ideal in BMI and the other in WHR. For pairs in which deviations in BMI and WHR were equivalent, the WHR-manipulated silhouette was usually regarded as the more attractive. This means that a departure from the ideal silhouette in BMI is more detrimental for attractiveness than in WHR. Therefore, BMI is more important for attractiveness of female body than WHR. Choices for pairs in which BMI and WHR diverged from the ideal to different degrees showed that a departure in BMI is as detrimental for attractiveness as the redoubled departure in WHR. In this sense, BMI is twice as important for female attractiveness as WHR. The conclusion of greater importance of BMI than WHR is also supported by the observation that the most preferred BMI depended on the BMI of the initially seen silhouette, whereas the initial WHR did not influence the choice of the most attractive WHR.

The predominance of BMI over WHR in determining attractiveness was independent of the rater's sex but increased with the degree of manipulation. Specifically, the predominance was small for departures from the ideal less than 1 SD and considerable for larger ones. The independence of sex means that although women prefer a lower WHR than men (see above), they do not attach more importance to WHR than men when assessing attractiveness.

Because we assumed the equivalence of BMI and WHR changes in terms of SD (i.e., a change by 1 SD of BMI is equivalent to a change by 1 SD of WHR) and the intensity of selection for a trait is expressed in units of the trait's SD (Falconer 1960), our results suggest that in modernized societies, a stronger sexual selection acts on female BMI than WHR. This selection is directed mainly against overweight/obese women (Puhl

and Heuer 2009) and operates through differential probability of marriage, age of marriage, and investments from the partner (Jokela et al. 2007; Pawłowski et al. 2008; Puhl and Heuer 2009).

The conclusion of the greater role of BMI than WHR for female attractiveness can be questioned on the grounds that BMI variation is exaggerated in affluent societies because of the large percentage of overweight and obese people in such societies. If so, the manipulation of our stimuli in BMI, based on its SD, was too large, leading to an overestimation of the role of BMI for attractiveness. We then compared SDs of BMI and WHR in young women from Poland (Pokrywka et al. 2006) and Tsimané, a native Amazonian society of forager-horticulturalists (Sorokowski P, Kościński K, Sorokowska A, Godoy R, Huanca T, TAPS Bolivia Study Team, in preparation). The variation of WHR in 180 nonpregnant, non-breastfeeding Tsimané women aged 18–30 was similar to that in 115 Polish women at the average age of 20.3 (SD = 0.05) but BMI variation was smaller in the Tsimané women (SD = 2.2) than the Polish women (SD = 3.2; Bartlett's test for equality of variances: $\chi^2_1 = 20.2$, $P < 0.001$). In the main study, we obtained that a departure in BMI was as detrimental for attractiveness as the redoubled departure in WHR. If the 2:1 proportion (departure by 2 SD in WHR being equivalent to departure by 1 SD in BMI) was recalculated into values characteristic for the traditional population, a proportion of $2:(3.2/2.2) = 2:1.45 = 1.38$ is obtained, indicating that BMI is more important for attractiveness than WHR by only 38%. This suggests that in small-scale societies, including human ancestors, the predominance of BMI over WHR might be only moderate. This numerical reasoning, however, requires empirical verification.

Literature data indicate that WHR is at least as important for health and survival as BMI (Singh and Singh 2011; World Health Organization 2011), so it can be expected that people will value WHR no less than BMI when choosing a partner. Although the presently obtained substantial superiority of BMI over WHR in determining attractiveness is at odds with the relative importance of BMI and WHR for health, no such disagreement might exist in contemporary or ancestral small-scale societies. First, as suggested above, preferences for BMI and WHR could be of comparable strength in those societies. Second, low body mass is quite frequent in such societies (Brown and Konner 1987) and may indicate undernourishment, poor resistance to hunger (due to little energy stored in fat), and physical weakness (due to low muscle mass), being therefore more critical to health and survival than overweight and obesity is in affluent populations (Brown and Konner 1987). Furthermore, Pawłowski and Dunbar (2005) found in a Polish sample that a newborn's birthweight (a powerful predictor of infant mortality and future health) was more strongly related to the mother's prepregnant WHR than BMI for women heavier than 60 kg, but the opposite was true for women lighter than 60 kg. The weight of women in traditional populations is usually less than 60 kg—for example, it averages 52 kg in the Tsimané women (Sorokowski P, Kościński K, Sorokowska A, Godoy R, Huanca T, TAPS Bolivia Study Team, in preparation). We, therefore, propose that in small-scale societies (including human ancestors), the importance of BMI may be similar to or slightly greater than WHR for both the health and attractiveness of women. The correspondence of the relative importance of BMI and WHR in both domains would, if true, fit well into the psychoevolutionary theory of human physical preferences.

CONCLUSIONS

The main conclusions from the present study are as follows:

1. Men and women prefer underweight, and frequently severely underweight, women. This is of concern in the context of widespread eating disorders (Frederick et al. 2006).
2. Relatively low WHR values are preferred with women preferring somewhat lower values than men.
3. Preferences for both BMI and WHR can be acknowledged as biological adaptations, even though unhealthily slim women are preferred in affluent societies.
4. Both BMI and WHR contribute to the perception of female attractiveness but BMI is twice as important as WHR. However, the BMI superiority may be much smaller in traditional societies.
5. Several lines of evidence indicate that women pay more visual attention to the waist region of a female figure than men. Future research should address reasons for this phenomenon.
6. Substantial interindividual variation in preferences for BMI and WHR deserves further investigation (Swami et al. 2009; Kościński K, unpublished data).
7. Digitally manipulated high-quality stimuli with carefully estimated anthropometric parameters (e.g., BMI, WHR) are recommended for future research on perception of the human body.
8. Choosing the more attractive stimulus from a pair in which each stimulus differs in some respect from the judge's subjective ideal seems a promising method for future research on the relative importance of features for attractiveness and other subjectively perceived characteristics.
9. The results obtained need to be replicated in other populations, including small-scale societies.

SUPPLEMENTARY MATERIAL

Supplementary material can be found at <http://www.behco.oxfordjournals.org/>

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Supplementary Material

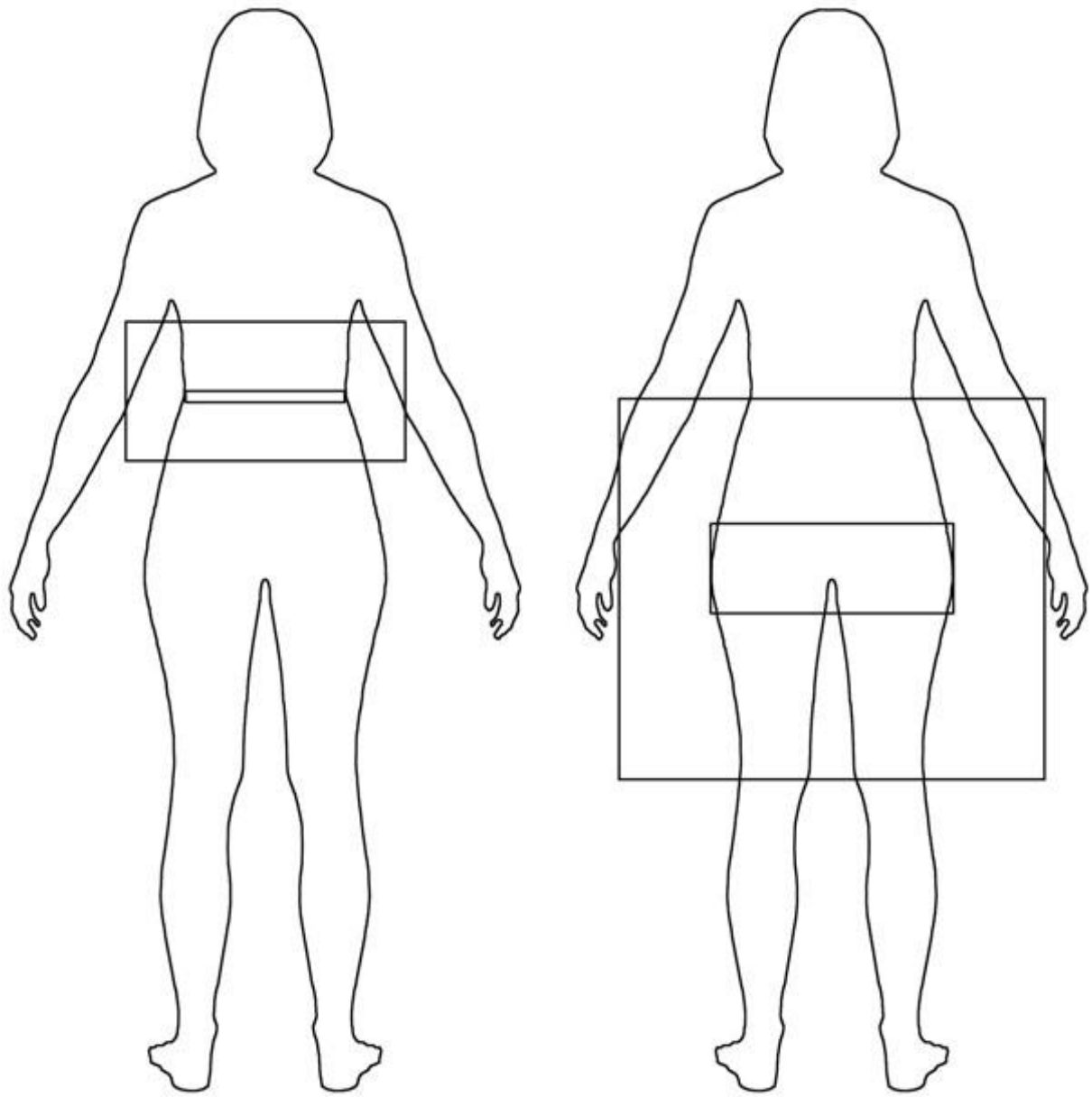


Figure S1. Definition of regions for waist (left) and hip (right) width modification. A change in width of the imagined inner rectangle causes the pixels inside the rectangle to move horizontally and proportional to the distance of the pixel from the rectangle's vertical axis of symmetry. Furthermore, the pixels inside the outer rectangle (but outside the inner one and excluding the arms) move horizontally and proportional to the distance of the pixel from the rectangle's vertical axis of symmetry, and to the vertical distance of the pixel from the inner rectangle. Pixels outside the outer rectangle remain stationary. The location and size of the rectangles were achieved by trial and error so as to yield a natural looking body shape for waist-to-hip ratios between 0.60-0.85.

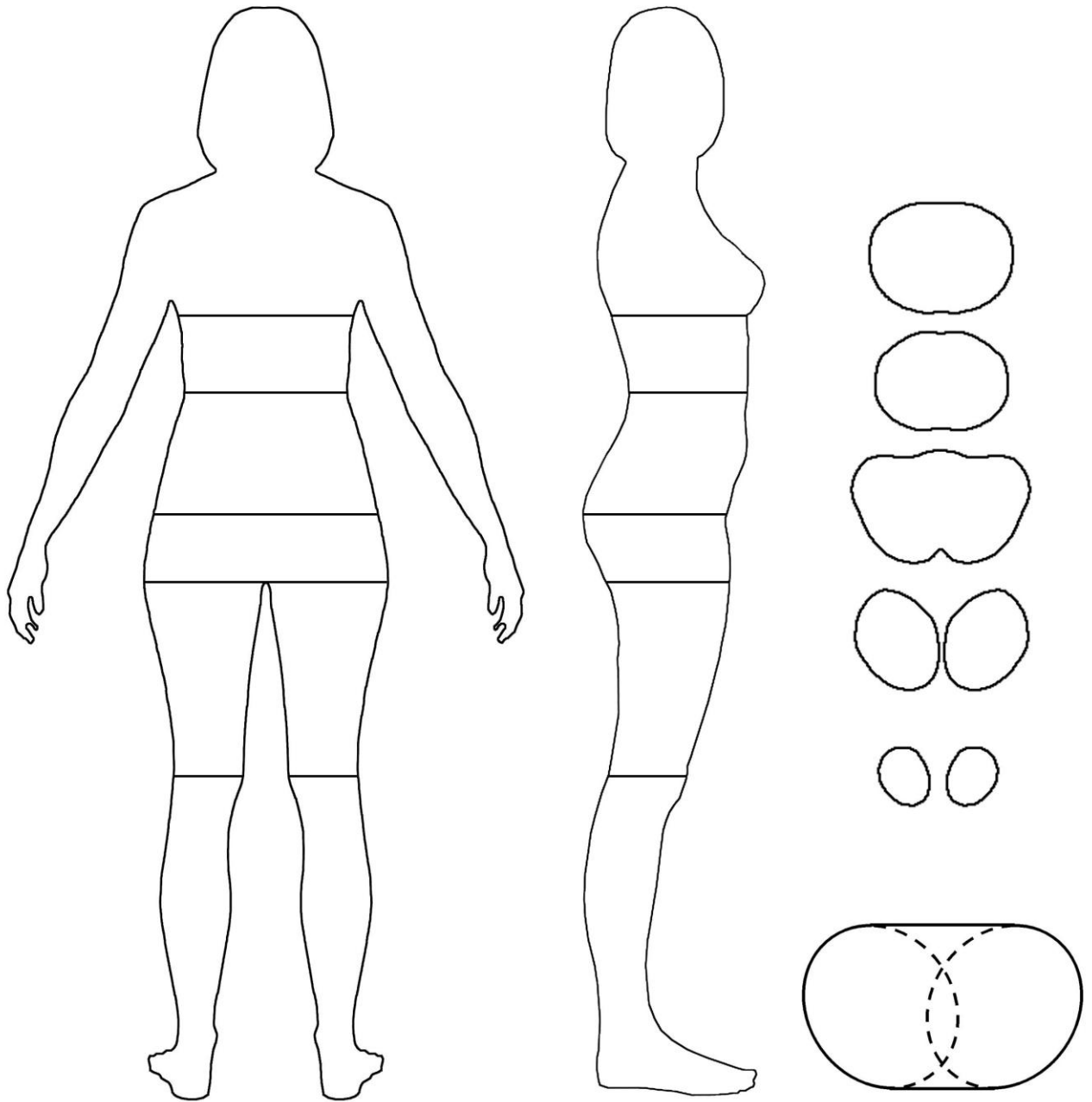


Figure S2. Analysis of female body shape. Left: To determine depth-to-width proportions, rear- and profile-view horizontal dimensions of 22 real women's silhouettes were measured at 100 levels, including 20, 30, 10 and 40 levels in breast-waist, waist-buttocks, buttocks-crotch and crotch-knees segments. Right: Shapes of horizontal body sections at chest, waist, buttocks, crotch and knees were obtained from an analysis of Victoria, a three-dimensional model of a woman's figure (body fronts are upwards). Right bottom: Estimation of hip circumference with two half-ellipses and two line segments. Two ellipses, with one axis equal to hip depth and the second equal to half of hip width, were enlarged by 4%, rotated to fit the lateral body outline and cut at their topmost and bottommost points. The total length of line segments in front and back of the body was 90% of the hip width. The Peano's formula for ellipse perimeter was applied: $\pi \times [1.5 \times (\text{width}/2 + \text{depth}/2) - \sqrt{(\text{width}/2 \times \text{depth}/2)}]$.

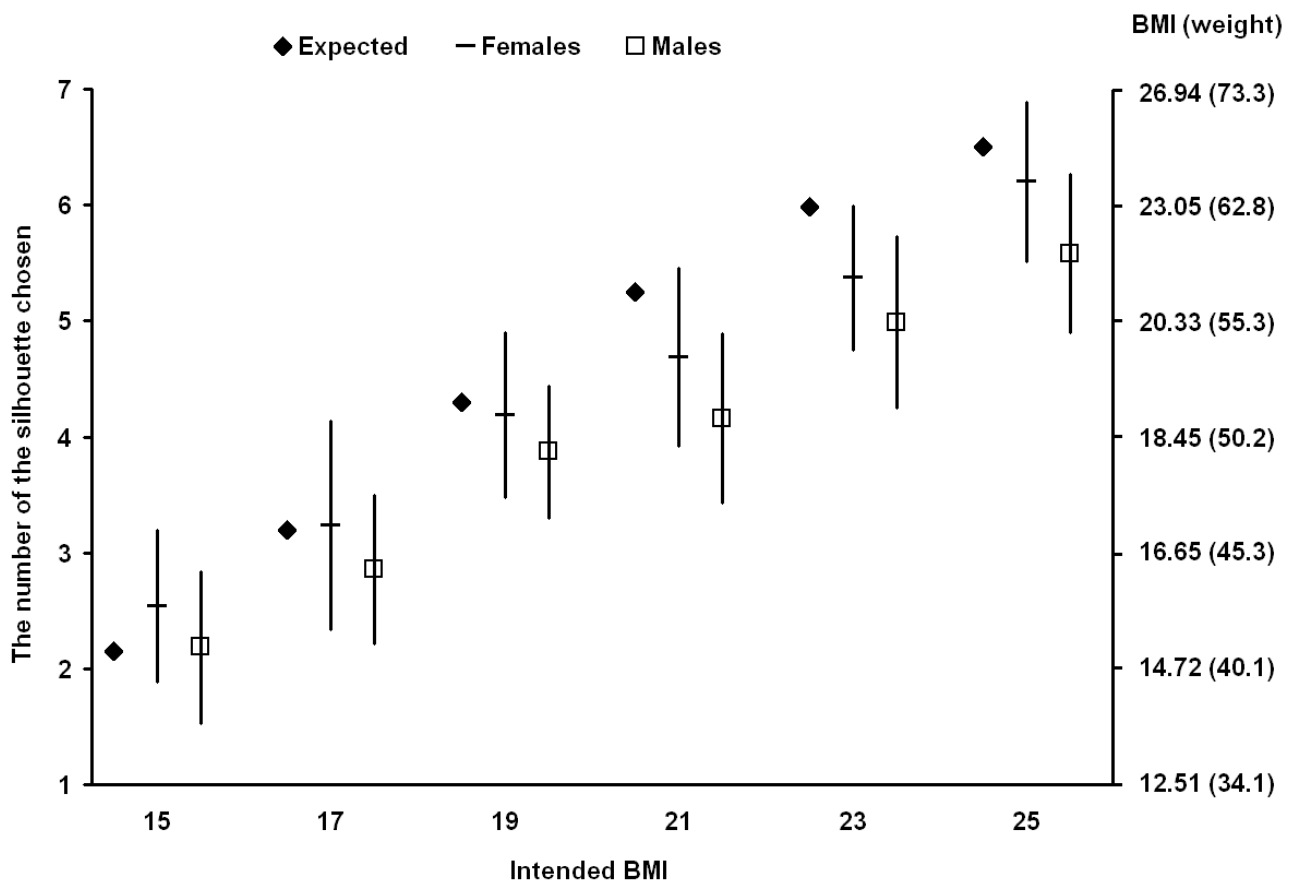


Figure S3. Expected and actual choices (means $\pm$ 1 *SD*) by women and men in the validation test. The corresponding BMI and, assuming a typical stature of 165cm, body weight values (in kilograms) are provided on the right axis.