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THE SHAPING EFFECT OF BODY SHAPERS ON FEMALE ATTRACTIVENESS

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A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Philosophy

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CERTIFICATE OF ORIGINALITY

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This work is dedicated to my beloved family, teachers especially my thesis supervisors and friends. Thank you very much for their love, consideration, patience and encouragement.

ABSTRACT

Body attractiveness is the perception of the physical traits of an individual human body, as attractive or beautiful. The variety of judgment was believed to be dependent on different culture/society and time period. Recent empirical results have provided evidence that body attractiveness of subjects with wearing standardized clothes during the tests were determined by a number of body ratios, such as Golden proportion, Wacoal golden indices, Body Mass Index (BMI), Waist-To-Hip Ratio (WHR), Volume Height Index (VHI). To increase body attractiveness, body shaper becomes a kind of hot undergarments which are believed to be able to beautify body contour shape by given shape-up effect. However, researches to date has not fully explored how effective the body ratios or other parameters are to explain the change of body shape by wearing body shaper. Therefore, this study aims to investigate what parameters can effectively indicate body attractiveness on apparent variation in consideration of the effect of wearing body shapers.

In this study, 18 Hong Kong young women with normal weight (BMI range from 18.5 to 24.9kg/m^2) were selected from 80 women. 15 styles of bras and 8 styles of girdles with four leading brands were chosen from the local market. 40 professional undergarment consultants with average 5 years working experience were invited to be judgers in this project.

Based on the Pair-t Test results, the women subject images with wearing body shaper have rated significantly higher than the nude subject images. For the correlation analysis, it was found that explanatory power of body ratios on change of body attractiveness after wearing different body shapers was limited. Therefore, other body parameters relating body contours were considered as variables which may determine body attractiveness perception tested by Multiple Regression equations development. Under the review of scatter plots, judges considered two different groups of parameters when judges determined women subject images were below 5.5 attractiveness ratings or women subject images were between 5.5 and 9 attractiveness ratings. Meanwhile, based on the attributes of Multiple Regression equations, the negative slope of each body parameters included in the equations indicated that judges tend to perceive subject images with giving a ‘base’ score and then deducting certain score due to unattractive level of each of body parameters which included in the Multiple Regression equations. According to the above statistical analysis result, obviously, breast and hip proportions are two key parameters to determine the whole body attractiveness, One-Way ANOVA showed that breast and hip contour attractiveness were two major contour segments that influence whole body attractiveness ratings. The high coefficient of determination obtaining from the Multiple Regression equation showed that breast contour attractiveness and hip contour attractiveness explained majority of whole body attractiveness. It also revealed that breast contour attractiveness and hip contour attractiveness contributed almost even significance on prediction of whole body attractiveness respectively.

The research results established clear picture of judges' perception and judgment attributes on whole body attractiveness. It contributed knowledge for assessment the shape-up effect of body shapers on improvement of the whole body attractiveness.

PUBLICATIONS ARISING FROM THIS THESIS

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1. Yu W., Li Y.B., Zheng Y.P., **Lim N.Y**., Lu M.H. and Fan J.T. (2006) Softness measurements for open-cell foam materials and human soft tissue, *Measurement Science and Technology*, 17, 1785-1791.

BOOK CHAPTERS IN RESEARCH MONOGRAPH

2. **Lim N.Y.**, Zheng R., Yu W.M. and Fan J.T., Assessment of women's body beauty, Yu W.M., Fan J.T., Ng S-P. & Harlock S. (2006) *Innovation and technology of women's intimate apparel*, Woodhead Publishing Limited.

3. **Lim N.Y.**, Yu W.M., Fan J.T. and Yip J., Innovation of girdles, Yu W.M., Fan J.T., Ng S-P. & Harlock S. (2006) *Innovation and technology of women's intimate apparel*, Woodhead Publishing Limited.

4. **Lim N.Y.**, Ng S.P., Yu W.M. and Fan J.T., Pressure evaluation of body shapers, Yu W.M., Fan J.T., Ng S-P. & Harlock S. (2006) *Innovation and technology of women's intimate apparel*, Woodhead Publishing Limited.

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CHAPTER 1

INTRODUCTION

1.1 Background

Beauty is defined as “a delightful quality associated with harmony of form in the eye of the beholder”[1]. This implies that beauty depends on the perception of eye of the beholders that have different standards for physical attractiveness in every culture. In previous investigations, researchers found that the perception of beauty was influenced by socio-cultural environment, race, skin colour, sex and mass media. Furthermore, the appreciation of women’s body shape varied in different countries due to their unique cultures, customs and fashion trends[2 3]. It is generally believed that there is no universal standard of human body beauty and physical attractiveness is rapidly changing[4].

In all years, body attractiveness is the ultimate goal of women in any part of the world[5]. Some aspects of how body traits are judged attractive are universal to all human cultures. "Harmony of form" implies balance among different components, which is largely determined by the proportion and symmetry of an object[6]. Recent literature has proposed a number of body ratios such as Body Mass Index (BMI), Waist-To-Hip Ratio (WHR), Volume Height Index (VHI) and Golden canyon. A range of determining numbers was suggested to represent body attractiveness that did not change across time and cultures[7].

In recent years, the body-shaping function of the shape-up undergarments became a topic of rumors in the Asian Pacific countries e.g. China, Japan, Korea, and Thailand etc. It will be interesting to investigate whether and how the body contour influences the overall body attractiveness of a woman. However, very little literature has reported the clothed effect on the visual body attractiveness. According to the study of Lapitsky et al [8], the female subjects thought clothing was important to form favorable perceptions for that were dressed attractively. Delong et al [9] believed that the form of dress indicated the ideal shape associated with a female body, when it was completely covered and shaped into body curves. These curves were defined as body contour, i.e. the outline of a body figure [10]. Etcoff [11] noted that smooth texture, symmetrical and curved shape body was essential for the desired shape of body.

As women's body shape can be altered by a foundation garment, which may affect the natural profile of some body parts. Therefore in this study, the body contour traits on smoothness, symmetry and shape will be identified and presented by mathematical body parameters such as body anthropometry, geometric measurements and body ratios. How significantly the body parameters predict body attractiveness with or without shape-up undergarments will also be investigated. This not only helps garment designers to identify the general norm of a beautiful woman body, but also provides guidance for individual women to understand how the body shaper can change her attractiveness.

The findings identified the ideal breast angle and hip angle that serve as an important guideline for bra and girdle design. Manufacturers and designers can understand better the amount of required shaping expected from body shapers. The multiple regression equation also provides an easy way to estimate the overall women's body attractiveness based on the key body parameters achieved by a garment.

1.2 Objectives

The overall aim of this project is to study the effects of body shapers on the geometrical body parameters and the subjective perception of women's body attractiveness. The followings are the five specific objectives,

- To examine the change in body attractiveness after wearing different body shapers.
- To identify the correlation between whole body attractiveness and different developed body ratios on the clothed and unclothed women subject images.
- To establish equations to interpret the effects of body parameters on whole body attractiveness
- To investigate the influence of body contour attractiveness on whole body attractiveness.
- To establish equations to interpret the effects of key contours attractiveness on whole body attractiveness.

1.3 Scope of study

In this study, eighteen Chinese female subjects, aged 10 to 26, with normal weight range (BMI is around 18.5 to 24.9kg/cm^2) were recruited. Advance instruments for landmarking and anthropometry measurement were applied to obtain comprehensive data sets of body measurements, body structure, body ratios and contour traits. Subjects' 3D body figures with and without wearing body shapers were scanned by Tecmath Body Scanner. Thirty Lingerie-fitting consultants with average five years relevant working experience were invited to assess the body attractiveness of the scanned images.

CHAPTER 2

LITERATURE REVIEW

This project investigated the relationship between whole body attractiveness and body parameters with clothed effect. The review of literature provides the definitions of major concepts relevant to the research, as well as empirical findings of previous studies dealing with major variables of this study. Body attractiveness is related to socio-demographic background, body ratios, body sizes, body contour traits and clothed effect. The literature review is therefore intended to cover the contributions in different related fields. In this Chapter, the literatures are grouped and reviewed in the following categories:

i) Socio-demographic background (Age, Race and skin color, Sex, Mass Media)
ii) Body ratios (Golden Section, Wacoal Golden Indices, WHR, BMI, VHI)
iii) Body sizes (Hip size, Breast size)
iv) Body Contour traits (Contour Symmetry, Contour Smoothness and Contour Shape)
v) Clothing influence on body beauty

2.1 Socio-demographic background (Age, Race and skin color, Sex, Mass Media)

Socio-demographic background of a woman such as age, social culture environment, race, skin color influences her body attractiveness. The gender of the judges and the fashion image promoted by mass media also affect people's judgment of beauty. Therefore, all these factors were studied and presented in the following sections.

2.1.1 Age

A number of studies including Lennon [12] confirmed that age is an important component of physical attractiveness. In the test, body images of female models with different age group were assessed and correlated the score with body measurement such as waist and hip width and depth. The result showed that as age of a female model is getting older, her perceived feminine body attractiveness becomes lower. Attractiveness is negatively correlated with the perceived age[13]. Attractive figures are always perceived as youthful.

2.1.2 Race and skin colour

Previous literatures confirmed that human's race and skin colour influence the body attractiveness. Anderson *et al.*[14] reported that fat body figure was attractive in the societies with limited food resources. The opposite occurred in the western societies where most people had excessive food. Furnham and Baguma [15] discovered that people in developing countries, such as Kenyan Asian and Ugandans perceived thin female shapes slightly more negatively than British did. They preferred obese females more than the British did. From the finding of Adrian[13], the Greek and British judges clearly showed their preference for petite size no matter of their weights.

Besides, Powell and Kahn[16] found that thin white women and heavy black women were considered “better” than heavy white women and thin black women. Other researchers also mentioned this halo effects. Harris *et al.*[17] found that black men were more likely than white men to find overweight women as attractive. Crago, Shisslak, and Estes[18] reported that black Americans were less prone to the influence of a thin beauty standard. Cohn & Adler[19], Cunningham *et al.*[20] and Monello & Mayer[21] reported that lighter weight was associated with beauty for white women.

Walter *et al.*[22] also found that men hold the strongest skin color biases regarding notions of feminine beauty. Hill Rozin claimed that dark-skin made African American women perceived less attractiveness.

2.1.3 Sex

Furnham *et al.*[23]; Henss[24]; Tovée[25] found that there was no significant differences in the rating of attractiveness by male and female raters. However, Fallon & Rozin[26], Rozin & Fallon[27] reported ratings of the female images by men and women produce gender differences. Shih and Kubo[28] found that female figures rated by women as more attractive were thinner than the figures preferred by males. Buss[29] believed that women had a very precise and accurate idea of what men found attractive.

2.1.4 Mass Media

Mass media predisposed women to be anxious about their imperfect body beauty figure[30]. It was the main way for young people to learn about skinny-yet-medium-busted figure ideal[31]. Fouts and Buggraf[32]examined the television situation comedies and found that thinner female characters received more positive comments.

Literatures [33]reported a significant decrease in the body measurements and weights of centerfold Models and pageant contestants from 1950s to 1990s. In the average bust, waist, hip measurements for Playboy centerfold Models were 90.8, 58.6, 89.3cm respectively[34]. This ideal represented a woman with bust-to-waist and hip-to-waist ratios of 1.5.

2.1.5 Summary of Socio-demographic influences

The previous findings showed that socio-demographic background, for example age, race and skin color, sex and mass media, influenced over subjects and judges in determining the attractiveness perception from subject body profiles. However, there is no common standard to define and identify the effect of socio-demographic background into quantified terms. Therefore in this project, similar socio-demographic background of the subjects was required so as to alleviate the effect of confounding factors in the experiments.

2.2 Body ratios (Golden Section, Wacoal Golden Indices, WHR, BMI, VHI)

2.2.1 Golden Section

Beauty is the pleasure through the perception of balance and stimulus of proportion. Camille Paglia[35] quoted 'By beauty we make objects, giving them limit, symmetry, proportion'. The Golden Section is a proportion that has been known since antiquity and possessed inherent aesthetic value because of an alleged correspondence with the law of nature or the universe[36].

The Golden Section was defined as a line proportion, which is 1: 0.6180399. It is a generic foundational concept of good proportion, which has been applied in architecture and art, such as the construction of the great pyramids, and the Greek sculptures named Dorifor's statue (Figure 2.1)[37]. In 560-480 B.C, Golden Proportion was used as the standards of human beauty and the samples of a harmonic body on art.

Figure 2.1 Body beauty under Golden Section in Dorifor's statue

Leonardo da Vinci (1451-1519) discovered that linear perspective was used by the painting technology on dividing different parts in human figure[38]. In 1854, Zeising, Hambidge[39], Doczi[40], Petuhov[41], Shaparenko[42] all indicated the presence of the golden proportion in a correlation of the body parts of man, specifically the hand. It is the fundamental principle of all formations striving to beauty and is the ideal of all figurations and formal relations to achieve perfect realization of the human figure.

In 1997, Marquardt investigated the universal use of Golden Section by applying it in many aspects, including human body. His study investigated the division of human body into several segments based on Golden Section. Golden Section was a formula developed by mathematicians; this formula was widely used to present body proportion of men in art because it stands for balance and beauty in history of Greeks[43]. However, Golden Section only depicted simple body linear measurement that may not be adequate to explain women's whole body attractiveness. Based on the foundation of Golden Section, Wacoal carried out some research works and recommended the best proportion among breast, waist and hip.

2.2.2 Wacoal Golden Indices

Wacoal has developed several indices to define body shape beauty as "Golden Proportion" (1955), "Beautiful Proportion" (1979) and "Golden Canon" (1995)[44]. In 1955, the "Golden Proportion" presented that the ideal body height was 162cm, equal to 7.3 multiples of head height. The ideal ratio of breast: waist: hip was 53: 37: 55, whereas the ideal hip height was the half of total body height. In 1979, the book

"Beautiful Proportion" defined body beauty in terms of a proportion of body height for different age groups. In 1994, among 1115 women, 129 women were assessed as having beautiful body figures. Based on the manual anthropometrical measurements and three-dimensional scanning data, six critical parameters to identify body beauty were obtained[45] as the Wacoal Golden Canon Ratios. The body types of women were divided into few groups based on the following body part ratios as shown in Figure 2.2: -

a) Ratio of bust girth to waist girth versus ratio of hip girth to waist girth

b) Ratio of bust width to waist width

c) Breast tendency of round shape versus tendency of inner direction

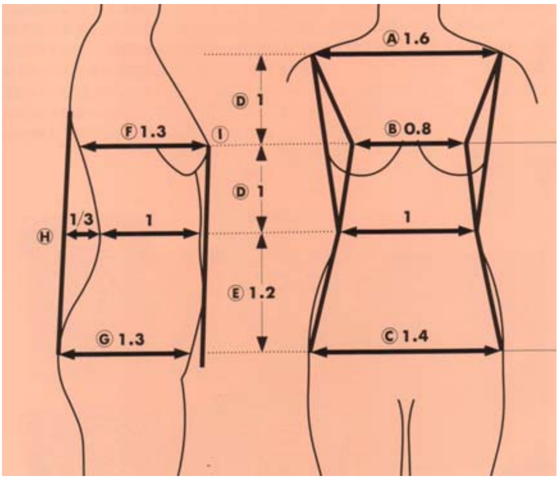
d) Hip tendency of trapezium shape versus tendency of lifting direction.

e) BMI

f) Ratio of head height, thigh height and hip height to body height

Based on the findings, the optimal body figures were identified in terms of the width proportion of breast: waist: hip as 1.3: 1: 1.4 and depth proportion of breast: waist: hip as 1.3: 1: 1.3.

Figure 2.2 Torso width ratio and torso depth ratio



2.2.3 Waist-to-Hip Ratio (WHR)

According to the body figures of Playboy centerfolds, Miss America contestants and fashion Models in America and England, the current ideal of feminine beauty comprises of a body which was thin, less curvaceous or tubular and androgynous. The significant decline of average body weight over the past 30 to 40 years concluded that the ideal female shape had changed to a taller, slimmer and less rounded one[46 47 48]. The study of Furnham and Alibhai[49] revealed that slim body figure was preferred in western countries and even borderline anorexic shape was not regarded unfavorably. The shape of the female body was determined by the amount of fat as well as the way it was distributed[50]. For judgments of physical attractiveness of body shape, Singh[51 52] claimed that the waist-to-hip ratio (WHR) as defined in Equation 2.1, it is an indicator of the distribution of body fat, which seems to be primarily important.

$$\text{WHR} = \frac{Waist\,circumference\ \ (cm)}{Hip\,circumference\ \ (cm)} \tag{2.1}$$

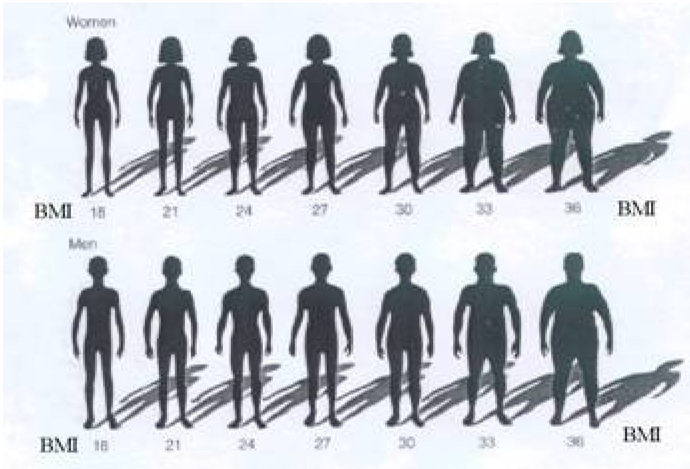
WHR was considered to be a ratio between fat stored centrally inside the abdomen (waist circumference) and fat stored peripherally (hip circumference)[53]. Singh[54] indicated that the range of WHRs of Miss America contest winners and Playboy centerfolds was within 0.68-0.72. Two famous actresses of different body sizes listed among Evian's 100 most naturally beautiful women had identical WHR. The smaller the WHR, the more exaggerated S shape of body curve would be. The Health Canada Office of Nutrition Policy and Promotion suggested that a healthy WHR for women should be below 0.8. Women in the age range of 18-85 years old regarded normal weight female figures with low WHR (0.7) were more attractive and healthy than those with higher WHR with same or lower body weight[54] [55]. The findings of Tassinary *et al.*[56] and Streeter *et al.*[57] further proved that WHR of 0.7 was more preferred than those with a higher WHR.

2.2.4 Body Mass Index (BMI)

In Figure 2.3, men and women's body figures in different BMI are shown and some investigators claimed that BMI was a far more important determinant of attractiveness than WHR. (Tovée *et al.*[58] [59], Tovée and Cornelissen[60] [61]). BMI of a person is the number obtained by dividing his weight (in kilograms) by the square of his height (in meters) as shown in Equation 2.2.

$$\text{BMI} = \frac{\textit{Weight (Kg)}}{\textit{Height}^2\ (m^2)} \tag{2.2}$$

Figure 2.3 List of human bodies with different BMI



According to the Canadian Dietetic Association, the silhouette (body shape) of women and men were related to their Body Mass Index (BMI)[62]. Since all successful female fashion and glamour Models were all fall within a narrow BMI, Tovée *et al.*[63] believed that BMI was the key determinant of female attractiveness. In adult, a person was considered underweight if his BMI is <18.5kg/m^2, he is considered normal if his BMI is 18.5 to 24.9 kg/m^2. He is considered overweight if his BMI is >25kg/m^2, he is considered obese if his BMI is >25kg/m[64]. Although, men and women may have different BMI standard level, in this research, Tovée *et al.*[65] did not mention in depth on difference of BMI that women and men should have.

In the study of Tovée[50], the perimeter-area ratio (PAR) (the path length around the perimeter of a figure divided by the area within the perimeter) with 0.97 correlation coefficient showed that the PAR is a better method to reflect body attractiveness than with BMI, rather than WHR. The analysis also showed that BMI accounted for 73.7% of the average ratings whereas WHR accounted for only 2.3%. Tovée *et al.*[61], Thornhill & Grammer[66] found the co-variation of BMI with WHR. That means if a subject chooses the least curvaceous shape, he is also choosing the highest BMI. In order to further understand the correlation between detailed representations of body shape with body attractiveness, Martin *et al.l*[67] analyzed the body shape by measuring the body width of 68 slices across the torso and across the legs. The result revealed that the unattractive bodies were much wider than the attractive bodies. That means body slice width (particularly lower body width) is highly correlated with BMI and highly negatively correlated with attractiveness ratings. The outline of the torso was treated as a waveform so that the body shape can be quantified and correlated with body attractiveness[32].

2.2.5 Volume Height Index (VHI)

To overcome the potential discrepancies on prediction of attractiveness by using line-drawn figures, Henss[68], Streeter and McBurney[69], Rozumus[70] used photographs for assessment. Tovée *et al.*[71] further derived their findings from using front and side views of photo images. Based on the findings of Tovée and Cornelissen[64], there was no difference in the perception of female attractiveness between images seen in front-view only or front and side view. In order to provide better quality of assessment, three-dimensional computer models of female bodies were introduced in the study of Fan[72]. In this study, Fan defined VHI as the total body volume (in liters) divided by the square of the height (in meters), which is shown in Equation 2.3.

$$\text{VHI} = \frac{Total\ \ volume\ \ (L)}{Height^2\ (m^2)} \tag{2.3}$$

VHI explained about 90% of the variance of average attractiveness ratings, which was higher than BMI of 80%. According to finding of Fan[73], the optimum VHI for Chinese viewers was about 14.1L/m^2 whereas that for Caucasians viewers was about 16-17.5L/m^2. Using linear multiple regression analysis, the effect of other body parameters could explain the attractiveness ratings. Body figures gained higher attractiveness ratings only when the body figures had greater prominence of bust, higher bust points, narrow bust point width, higher waist line (indicating long legs), smaller waist girth in relation to bust, abdomen, hip girth, higher hip position and bigger hip girth in relation to body height.

2.3 Body sizes (Hip size, Breast size)

Recent researches found that ‘size’ in different body parts might influence ratings of female body attractiveness, regardless to WHR.

2.3.1 Hip size

Tassinary and Hansen[59] reported that hip size was a stronger determinant of female figures attractiveness than WHR. Forestell *et al.* [74] found that larger figures with smaller hips were perceived as more athletic and thus more attractive than the more shapely heavy body weight alternatives. These results reflected that hip size could be important to predict women’s attractiveness perceptions. Although several studies of Singh & Luis [75] claimed that hip size was more influential than waist size, Malgorzata[76] showed that men were sensitive to WHR differences only based on waist change instead of hip change. That means when the waist size decreases, the attractiveness of the female figure increases. According Voracek and Fisher [77], Playboy centerfold Models had tendency to prefer smaller hip size and higher WHR from the last 50 years. Tovée *et al.* [78] discovered that over 90% participants of experiment perceived the subject with a bigger hip size as the heavier one. Therefore, the increased hip size of WHR from 0.65 to 0.6 might lead to the perception of increased weight as well, and caused the decrease in attractiveness rating.

2.3.2 Breast size

On the other hand, Singh and Young[79] reported that waist-to-hip ratio (WHR) and the breast size were the main factors to influence the judgments of female attractiveness, age and desirability for relationships. Kleinke and Staneski[80] found that medium breast gained most favorable ratings from the participants of both sexes. However, the research of Gitter *et al.*[81] showed that males preferred large breasts but only for small and medium female figures. Meanwhile, female preferred smaller breasts. Singh and Young[80] believed that the figure of slender bodies with low WHR and large breast was considered to be the most attractive, healthy, feminine looking, and desirable for both types of relationship. Low[82] claimed that slim young females with large breasts were the most attractive body figure. The finding of Adrian *et al.* [56] showed that breast sizes were relatively less important than WHR on influence of the attractiveness ratings, large breasts only slightly increased the rating of health and feminity. Heavy figure having a high WHR and large breast size was rated to be the least attractive and healthy one. It was inconsistent to the finding from Low[85] that attractiveness ratings for large breast women increased when WHR was low. In addition, the age estimations highly depended on breast size, WHR and weight, therefore, women with large breast, high WHR and high weight rose the perceived age by over ten years.

2.4 Body contour traits

Body contour was defined as the outline of a figure, which exposes on body surface[83] and represents the 2D silhouette of body whereas contour shape was defined as a reference point against which body attractiveness is judged[84]. The finding from Alley *et al.* [85] showed that body surface with smooth texture and bilateral symmetry leaded to the high attractiveness. In order to analyze the body contour attractiveness, the body contour traits that may affect the whole body attractiveness should be quantified and identified. Referring to previous studies[84] [85] [86], body contour traits such as smoothness, symmetry and shape were used to determine the attractiveness of body outline, although in qualitative terms mainly.

2.4.1 Contour smoothness

Edmund [86] believed that ‘Smoothness’ is a quality so essential to beauty. ‘Smoothness’ is easily admitted a constituent of visual beauty and this quality is found almost without exception in all bodies that are by general consent held beautiful. A smooth, clear complexion is an attribute of physical attractiveness[87]. Fink, Grammer & Thornhill[88], claimed that skin smooth texture was shown to have a positive affect on facial attractiveness ratings. Fan *et al.* [89] reported that fabric smoothness appearance was one of the essential clothing properties to determine visual body attractiveness. Another study from Fan *et al.* [90] [91] showed that seam pucker which represented as the curvature of the garment surface texture was negative related to garment appearance performance.

2.4.2 Contour symmetry

Research of Thornhill and Gangestad[92] has shown that minimal ordinarily bilaterally asymmetrical on human figures were judged to be most attractive. Singh[93] arbitrarily changed the symmetry of the bust in line-drawings stimuli and found the inverse correlation between breast asymmetry and attractiveness. However, it was argued that the finding was not realistic because it was not directly obtained from the attractiveness of real human body. Singh[94] showed that the figure with low WHR and symmetrical breasts was judged to be most attractive and had higher reproductive capability. The judgment of attractiveness, feminine looks and desirability for long-term relationship still were certainly influenced by asymmetry. Later, Tovée *et al.*[95] found that viewers perceived different attractiveness between symmetric images and normal asymmetric images in a two-alternative forced-choice experiment. Møller, Soler and Thornhill[96], Manning *et al.*[97] reported that breast-size symmetry positively affected women’s attractiveness.

2.4.3 Contour Shape

Contour shape was defined as the character or construction of contour as determining its external appearance so as to form a shape or a form[98]. The conventional measure of female body shape is WHR (waist/hip ratio), which was claimed to be major determinant of physical attractiveness. However, some later studies revealed that WHR was too simple and general[99]. Although other researches believed some ratios which indicated the proportion of weight or body volume with height (BMI, VHI) were better predictors to account for higher percentage of average attractiveness ratings, Anderson *et al.*[100] reported that women with the same bust, waist, and hip measurements can be completely different shapes with variations in posture, back curvature, hip positions, bust shape and legs etc. Therefore, the study of comprehensive measurements of contour parameters, which are contour angles, lengths and height to construct body contour shape, may be critical to determine physical attractiveness prediction.

2.5 Clothing influence on body beauty

La**B**at *et al.* [101] noted that body satisfaction level of the perceived overall body image was highly related to the satisfaction of the fit of clothing. Markee *et al.* [102] compared the body satisfaction level between the nude body and the clothed body of 29 working women, the results showed that the subjects with clothed bodies were significantly more satisfied than with their nude bodies. It showed the influence of clothing in enhancing perceived body attractiveness.

Women used various devices to shape their body according to the beauty criteria throughout history[103]. Undergarment is the typical clothing that helps to shape the wearer's body figure; the functional undergarment is also called 'Body Shaper'[104]. It is a form of undergarment which aims to tightly cover and shape body contour so as to achieve ideal body figure with beautiful outline. Women believed that undergarment represents society's ideal of beauty and femininity[105].

2.6 Summary

Body beauty is in the eye of the beholders so it can change with time and culture. The previous findings showed that socio-demographic background, such as age, race and skin colour, sex, mass media influenced the prediction of body attractiveness. However, there is no common standard to define and identify the effect of socio-demographic background into quantified terms. These factors were then controlled into narrow range in this project so as to eliminate the influence of socio-demographic background on body attractiveness judgment. According to the body ratios for predicting body attractiveness, the earliest theory of beauty was presented by the Golden Section, which is a generic foundational concept of good proportion, which has applied in architecture and art. However, there was no standard was found to judge body attractiveness of Chinese women based on Golden Section.

Over 40 years research works, the women body figures were classified into several types based on their body part proportion and the ideal body figures in different age groups with different generation were depicted in terms of proportion of head and body, proportion of breast: waist: hip at body width and body depth etc. Later, some studies presented that ratio of waist circumference and hip circumference (WHR) was an important indicator to determine body attractiveness because famous Models and actresses had similar WHR. However, other literatures showed that women who were rated with the highest whole body attractiveness were within narrow range of the ratio of body weight and height^2. Alternatively, some researches concluded BMI is the effective predictor to explain body attractiveness.

In recent years, the ratio of volume and height^2 (VHI) was found to be able to explain more variance of body attractiveness ratings than WHR and BMI. Apart from these body ratios, researchers also revealed that body size, especially some particular body parts such as breast and hip, could be used to determine the visual perception from judges. Referring to previous studies, numerous literatures[87, 88, 89] found that body contour traits in terms of smoothness, symmetry and shape were also studied to determine the attractiveness of body outline. Researches believed that the perceived whole body attractiveness was highly related to the fit of clothing. Clothing, especially the functional undergarment (Body shaper) tightly covers and improves body contour, is designed to achieve ideal body figure with beautiful outline and it is always influenced by the society’s ideal of beauty and femininity.

2.7 Knowledge gaps

Based on the extensive literature review, knowledge gaps have been discovered and listed in the following.

- The predictions by body ratios, such as Golden Canon Ratio, WHR, BMI, VHI on body attractiveness with clothed effect from body shapers have not known.
- Previous researches have not ever considered all body ratios, body structure, body anthropometry and geomorphic measurements and their proportion and body contour traits together to explain of body attractiveness.
- The influence of body contour beauty on the explanation of whole body attractiveness was ignored in previous studies.
- Limited research work focused on investigation of the clothed effect of body shapers on the prediction of whole body attractiveness

All the knowledge gaps listed above are the indispensable elements on the development of visual body attractiveness predictor to identify realistic ideal body shape. Therefore, substantial theoretical and experimental works have to be carried out.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this study was to first determine the influence of body parameters on the body attractiveness of Hong Kong young Chinese women who were in normal BMI range from 18.5 to 24.9 kg/m^2. The independent body parameters in this study included body geometrical and anthropometrical measurements, the body ratios from the proportion of body geometrical and anthropometrical measurements, body structure and body contour traits. This chapter delineates the subject selection; testing garment samples and describes the instruments and procedures of the following tests:

1. Manual anthropometry to determine good fit garment samples wearing during the experiments.
2. Body structure calculation, which was the measure of bone mass, muscle mass, total body water and body fat.
3. Body scanning to project body scanned images for subjective assessment and objective body measurements.
4. Subjective body attractiveness assessment on body scanned images
5. Objective calculation of body contour traits on body scanned images

In the last part of this chapter, the statistical approaches for analyzing data from the above tests will be described.

3.2 Subject Selection

As the age and weight difference would very much affect the body attractiveness, the subjects were required to be in a narrow range of age (20-26 years old) and BMI (18.5-24.9 kg/m^2). Based on these criteria, a small but carefully chosen sample can be used to represent the young Hong Kong Chinese woman population. The sample size calculation determines how many people should be recruited in the study in order to get results that reflect the target population as precisely as needed. According to Harris et al[17], the sample size can be determined by a formula:-

$$N = \left(\frac{1.96 * \sigma}{E} \right)^2$$

where

N = number of samples

1.96 = the critical value at level of significance α =0.05 on Normal curve

σ = standard derivation of attractiveness ratings

E = maximum allowable error of estimate

From the attractiveness ratings given by judges on all 108 body images, it was found that the standard deviation was 2.02. Assuming the acceptable error of estimate (E) is 0.5, according to the above equation, the sample size should be at least 16. This confirms that 18 women subjects were sufficient to represent the target population for body attractiveness assessment. To recruit the young Chinese women subjects, invitations for volunteers were posted in the Hong Kong Polytechnic University campus from 6^{th} of February to 6^{th} of March in 2005.

3.3 Testing Samples

As shown in Figure 3.1, fifteen styles of bras and eight styles of girdles were selected from the four leading brands in the local market. These so-called 'Body Shaper' all claimed to have good shaping up functions.

Figure 3.1 Bras and girdles used

Each subject was measured manually before selecting the correct sizes of body shapers for her, according to bra cup sizing chart in Table 3.1 and girdle sizing chart in Table 3.2.

Different between full bust and underbust	Cup size
7.5cm (3")	AA
10cm (4")	A
12.5cm (5")	B
15cm (6")	C
17.5cm (7")	D
20cm (8")	E also called DD
22.5cm (9")	F also called DDD or EE
25cm (10")	G also called FF or EEE

Table 3.1 Bra Cup Sizing Chart

Waist Measurement	**Hip Measurement**	**Panty Size**	
25"-26"	35"-36"	5	S
27"-28"	37"-38"	6	M
29"-30"	39"-40"	7	L
31"-32"	41"-42"	8	XL
33"-34"	43"-44"	9	XXL
35"-36"	45"-46"	10	XXXL
37"-38"	47"-48"	11	
39"-40"	49"-50"	12	
41"-42"	51"-52"	13	
43"-44"	53"-54"	14	
45"-46"	55"-56"	15	

Table 3.2 Girdle Sizing Chart

3.4 Anthropometric measurements

3.4.1 Purpose

According to the study of Fan *et al.*[92], clothing which dressed for good fit enhanced body attractiveness. In order to ensure that the selected body shapers were fit on the subjects' bodies, anthropometric measurement was taken manually to determine the bra size and girdle size suitable for individual subject[106].

3.4.2 Preparation prior to body measurement

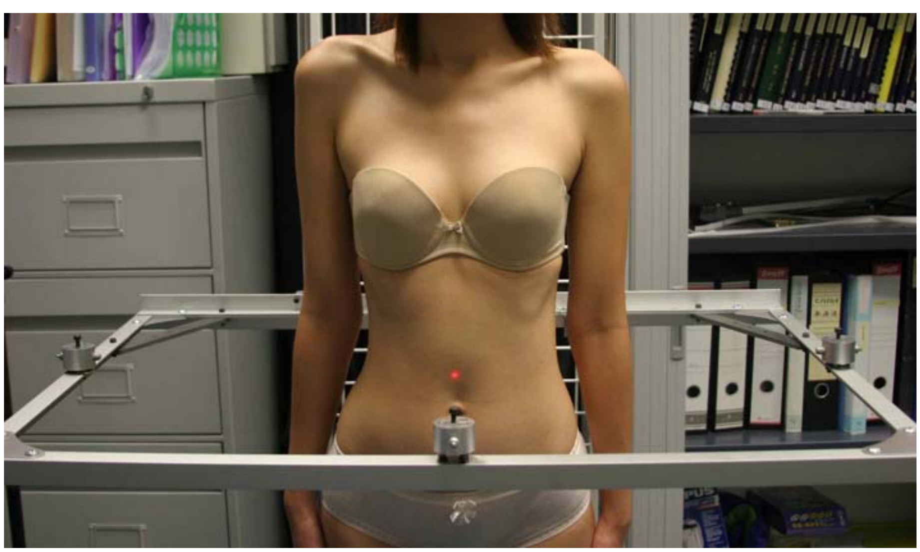
Before taking subjects' body measurement, subjects were asked to sign a consent form allowing their photographs to be used in this study. The experimental procedures were explained verbally and informed on written information sheet. At the beginning of the experiment, each subjects used nipple stickers. They wore close-fitting panty only, without shoes and jewellery. If the subject had long hair, a hair clamp was provided for tidying up the hair**.** Each subjects stepped on a pair of footprints and faced in front of mirror, stood naturaly straight and upright position with normal breath, weight equally distributed and arms fully relaxed at the sides.

Before the real manual measurement, the correct identification of body landmarks is one of key elements in the collection of accurate anthropometric data. A landmark is an anatomical structure used as a point of orientation in locating other structures.

3.4.3 Body landmarking

The body landmarking process is to mark certain places on the body with a non-smearing, skin pencil. A small cross was used as the marking symbol so the intersection of the lines was easier to read. In order to make a quick and accurate marking on body at the same horizontal level, a portable body landmarking device including 4 laser pointers was developed as shown in Figure 3.2. All 4-laser pointers were installed on a horizontal rectangular frame and the frame was suspended from the top of a vertical rod through a pulley. The frame was able to move upward and downward based on the height for landmarking.

Figure 3.2 Movable Laser Pointers Rod



Each subject stepped on footprint and moving the frame at the required altitude marked four body points at the same horizontal level. For body circumference measurement, four horizontal levels of bust, underbust, waist and hip were identified in Figure 3.3.

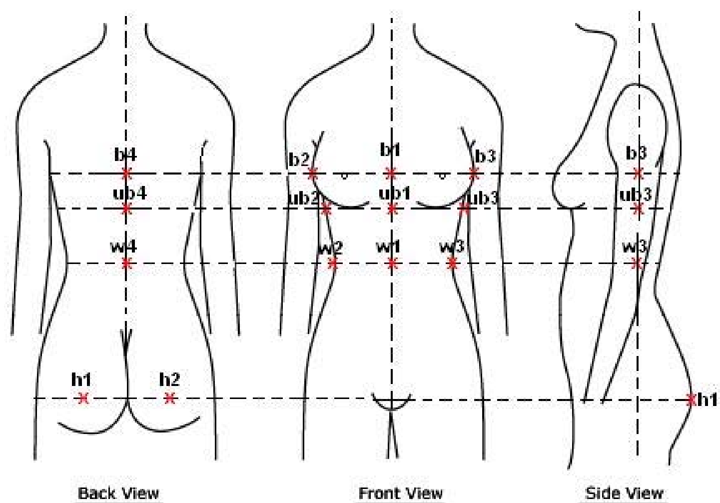
Fig.3.3 Body landmarks for measurements:

B1 – Center front of bust, **b2** – Right side of bust, **b3** - Left side of bust, **b4** – Center back of bust

Ub1 – Center front of under the bust, **ub2** – Right side have under the bust, **ub3** – Left side of under the bust, **ub4** – Center back of under the bust

W1 – Center front of waist, **w2** – Right side of waist, **w3** – Left side of waist, **w4** – Center back of waist

H1 – Outermost left hip, **h2** – Outermost right hip



Landmarking and anthropometric measurements were taken in three repeated times for the calculation of average results.

3.4.4 Manual measurements

Based on the body landmarks on the bust, underbust, waist and hip levels, body circumferences were efficiently and accurately measured by wrapping around the specific level using a plastic tape. The measurements required together with symbols for each subject are shown in Table 3.3.

For straight linear measurements, a professional KYS Martin's Anthropometaric stature gauge was used (Figure 3.4). The stature gauge was vertically fixed on a movable stand base for body height measurement. Subjects stood beside the rod, brought the straight leg in contact with the body for height (BO_{hei}) measurement. Besides, body weight (BO_{wei}) of subjects was also measured. The body weight divided by the square of body height gives a ratio of BMI.

Figure 3.4 Martin measurement devices

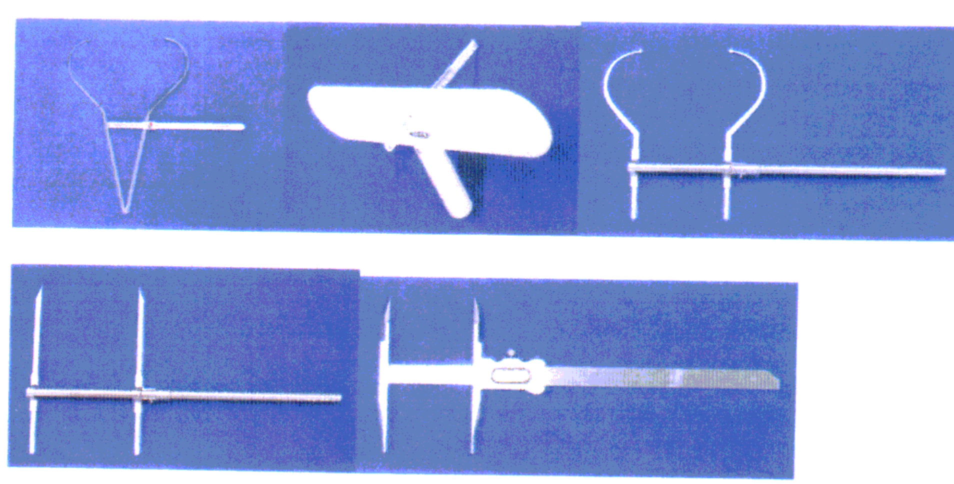


Table 3.3 Anthropometric measurements from KYS Martin's Anthropometaric stature gauge

Anthropometric measurements	**Symbol**	**Purpose**
Bust girth	B_g	Determination of bra size
Underbust girth	Ub_g	Determination of bra size
Waist girth	W_g	Determination of girdle size
Hip girth	H_g	Determination of girdle size
Body height	BO_{hei}	Calculation of BMI
Body weight	BO_{wei}	Calculation of BMI
BMI	Bo_{wei}/Bo_{hei2}	One of body parameters for further analysis

The Body Composition Analyzer (Figure 3.5) was used to measure the bone mass (B_m), muscle mass (M_m), total body water (Bo_{wat}), body fat (BO_f) as shown in Table 3.4. It can measure the differences of body impedance (resistance to a small electrical signal) from biological tissues such as muscle and fat. With a tiny electrical signal applied at the palms of subjects' hands, this conductivity was precisely measured and the percentage of body fat throughout the upper body can be computed. The subject entered her age, height, weight, and wrist size and pressed 'start'. Then it computed the body compositions from the impedance measurement. During the measurement, the subject stood still and straight without bending her elbows. The arms were held out parallel to the floor. Then the subject grasped the sensor under the palms firmly of both hands straight. The four body composition factors were measured within six seconds.

Figure 3.5 Body Composition Analyzer

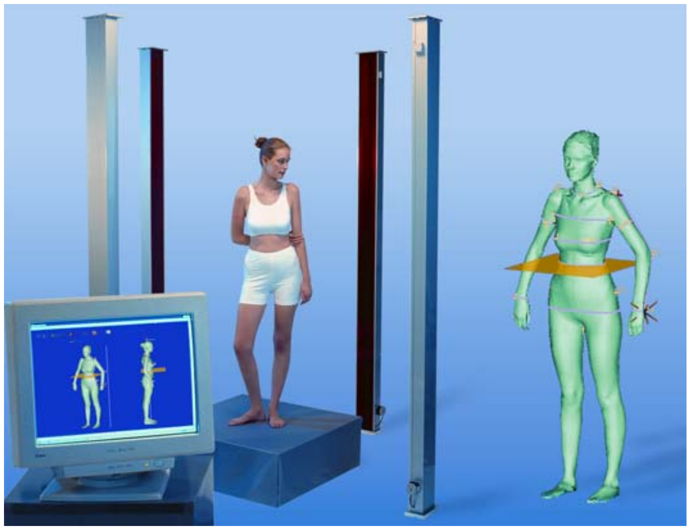
Table 3.4 Anthropometry measurements from Body Composition Analyzer

Anthropometrical measurements	Symbol
Bone mass	B_m
Muscle mass	M_m
Total body water	Bo_{wat}
Body fat	BO_f

3.4.5 Body Scanning

The eighteen female subjects were scanned by a TecMath Laser scanning system (Figure 3.6) that is one of the most popular three-dimensional laser body scanners in the world. The four class 1-laser rods have two CCD cameras in each laser rod. It took less than 10 seconds to scan an object and calculated body dimensions in less than 2 minutes. The distance between each of data points was 1mm in depth x 2mm in vertical x 1mm in horizontal level.

Figure 3.6 Techmath Laser Body Scanner



Before scanning, the subjects were informed verbally on the procedures of body scanning. They were requested to wear 5 different sets of body shapers in a given sequence.

The subjects took off all accessories, shoes and clothes except the panty. A white cap was used for hiding the hair. After the subject was dressed up appropriately, she was asked to enter a scanning room for body scanning. According to the guideline shown in the scanning room, she stepped on the footprint at the center of the four laser rods and stood naturally. Her two arms were required to be put apart from her body torso around 10 inches. In order to keep darkness in the whole scanning environment, the door was closed and the light was turned off when the subject was ready to be scanned. She was asked to keep the position without any movement until the scanner stopped. Each subject took six set of body scans, each set of scan repeated three times.

Figure 3.7 Body scanned profiles

3.5 Derived anthropometric data from scanned images

The automatic body measurements given by the scanner's software are mainly body lengths, heights and circumferences for fitting outerwear. Most of them are irrelevant to the contour traits required for the analysis of women's body attractiveness. Therefore, the raw data of 3D cloud was transformed and exported from body scanning system to a new developed computer program so as to calculate detailed body geometric parameters such as angles, area etc to depict contour traits.

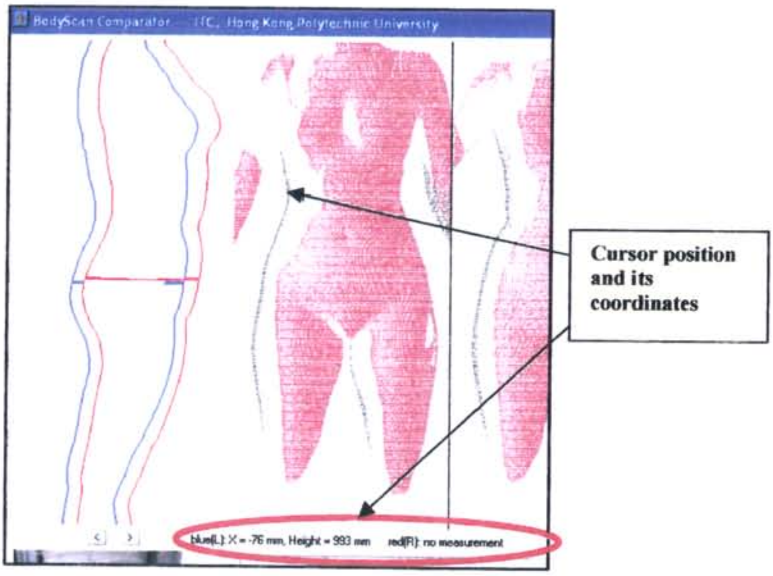
The scanned body profiles from side view and front view were visualized and analyzed by a program as shown in Figure 3.9. From the program, the four main categories of body measurements were obtained.

- Body height
- Body depth and width
- Body cross sectional area and volume
- Body contour smoothness, symmetry, shape

3.5.1 Body height

On the computer screen as shown in Figure 3.8, the mouse pointer identified a point on the side view or front view of the body profiles. Parameter X shown at the bottom of screen represents the relative position of the point to the vertical axis from left-right part of body (front view profile) or front-back part of body (side view profile). Parameter Y represents the body height from the cursor point to the ground. The height accuracy of the scan data was 2mm.

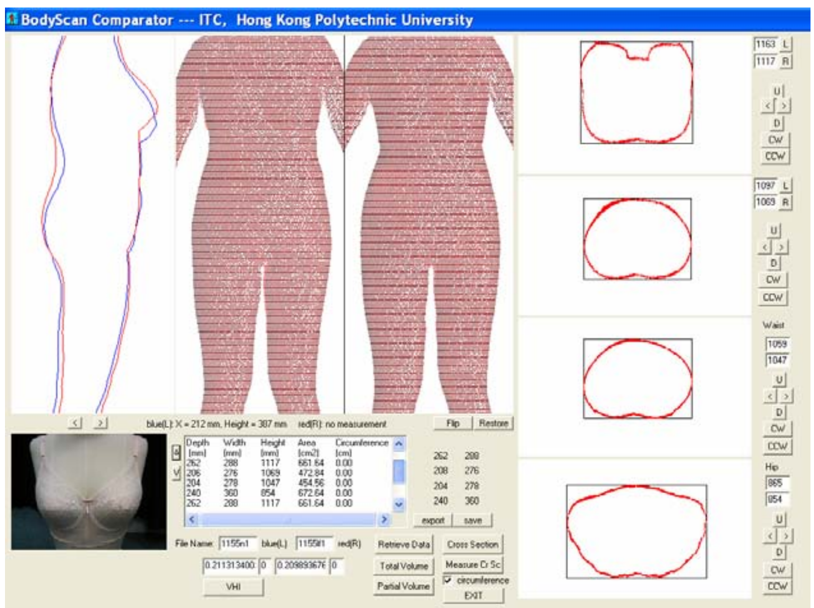
Figure 3.8 the position of the cursor and the relevant values



3.5.2 Body depth, width and cross-sectional area

Using the program, up to four cross-sectional profiles at specified height levels are shown in Figure 3.9. Each profile can be rotated until it looks balance in both left and right sides. The body depth and the cross-sectional area can then be calculated.

Figure 3.9 Body cross-sectional profiles



Based on the findings from Wacoal "Golden Canon" report[60], the proportion of Breast width, Waist width and Hip width in front view (BWH_f) and the proportion of Breast depth, Waist depth and Hip depth in side view (BWH_s) were important to indicate body attractiveness. In order to understand how these two body proportions influence average body attractiveness perception from judges, the depth and width of breast, waist and hip were derived and listed in Table 3.5 so as to calculate torso proportions (BWH_f and BWH_s) of subjects' bodies.

Description	Body geometrical data
Breast height	B_h
Waist height	W_h
Hip height	H_h
Breast depth	B_d
Waist depth	W_d
Hip depth	H_d
Breast width	B_w
Waist width	W_w
Hip width	H_w
Breast cross sectional area	B_{csa}
Waist cross sectional area	W_{csa}
Hip cross sectional area	H_{csa}

Table 3.5 Body anthropometric measurements derived from scanned profiles

3.5.3 Body cross-sectional area and volume

The whole body volume was obtained by integrating all cross-sectional areas from the neck to the toes with the aids of computer program. Since the scanned data were obtained while the laser scanning heads were moving in an interval of 2mm, the z-coordinate of two successive data is 2mm. The body volume and height of subjects were identified to calculate VHI (Volume/Body height^2) as stated in the study done by Fan *et al.* [75].

3.6 Body contour traits derived from scanned images

Body contour smoothness, symmetry and shape were studied as one of important indicators to determine body attractiveness in previous researches. In this study, the body contour traits which influenced the visual perception of body attractiveness were revealed, including:

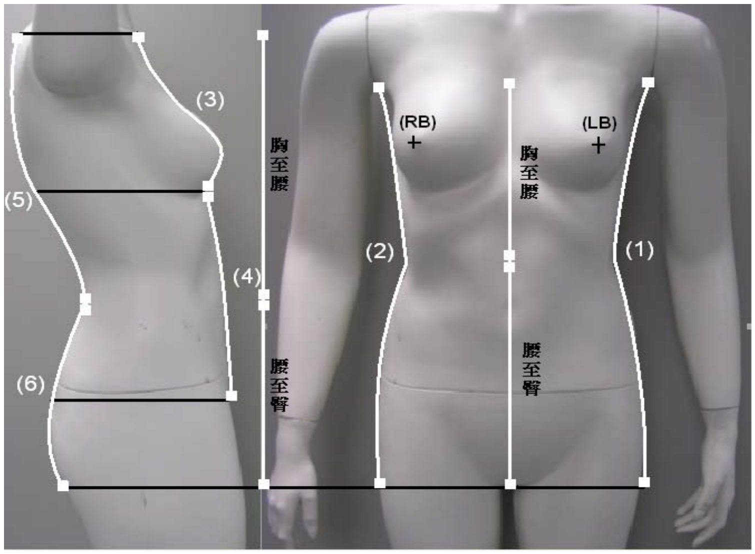
1) Contour smoothness - contour segments on (1) left (2) right (3) bust (4) abdomen (5) back and (6) hip (Figure 3.10)
2) Contour symmetry - side contour asymmetry, breast contour area asymmetry and breast contour asymmetry
3) Contour shape - Geometric measurements affecting hip and breast contour shape

These contour traits were also derived from the scanned images.

3.6.1 Contour Segments

Fan *et al.* [92] showed that fabric smoothness is essential to evaluate the clothing appearance which affects body contour attractiveness. Therefore, the change of contour smoothness of scanned body profiles after wearing body shapers was investigated in this study. In order to evaluate the degree of contour non-smoothness degree in different parts of body, the body contours were divided into six segments. Figure 3.10 shows six contour segments in Body contour guideline sheet which are labeled as (1) left (2) right (3) bust (4) abdomen (5) back and (6) hip.

3.10 Body contour guideline sheet with six contour segments



Before six contour segments were accurately determined as listed in Table 3.6, the eight body landmarks including (a) Neck, (b) Breast point, (c) Under breast, (d) Waist, (e) Hip, (f) Gluteal Furrow, (g) Center crotch and (h) Side crotch were identified manually from the computer screen (Figure 3.11).

Figure 3.11 Eight body landmarks

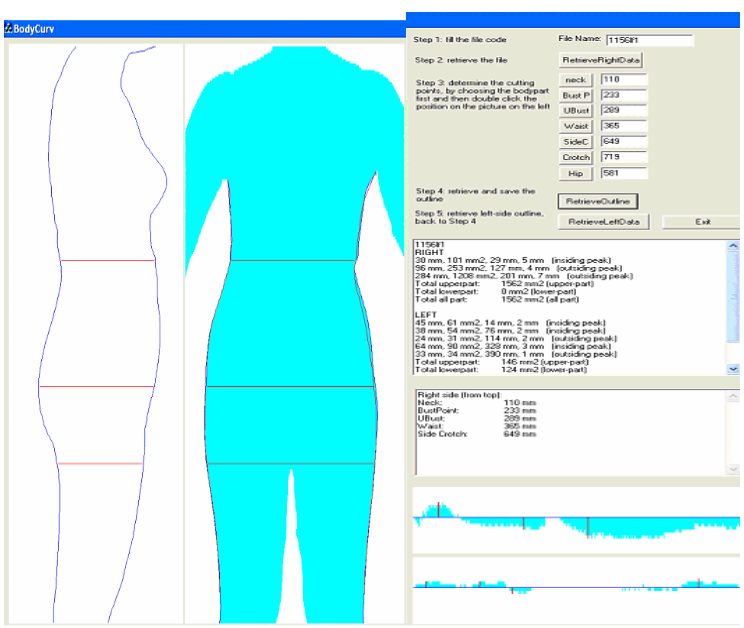


Table 3.6 Definitions and cursor identifications of landmarks

Code No.	**Landmarks**	**Definitions**	**Guideline for identifications**
(a)	Neck	Front (anterior) point at the base of the neck	Innermost point from neck to bust point at anterior body from right side profile
(b)	Breast point	Most prominent protrusion of the breast	The outermost point around the breast contour at anterior body from right side profile
(c)	Under breast	Least prominent protrusion of the breast	The innermost point around the breast contour at anterior body from right side profile
(d)	Waist	Location between lowest rib and hip	The innermost point from ribs to hip at posterior body from right side profile
(e)	Hip	Maximum protrusion of the hip	The outermost point around the hip contour at posterior body from right side profile
(f)	Gluteal Furrow point	The crease formed at the juncture of the thigh and buttock	The innermost point around the hip contour at posterior body from right side profile
(g)	Center crotch	Body area adjunct to the highest point of the included angle between the legs	The center point between highest points of two thighs from front profile
(h)	Side crotch	The juncture of the thigh and abdominal extension	The highest point of the right thigh from right side profile

3.6.2 Contour smoothness

The smooth contour segments were presented by 3rd order polynomial equations using curve-fitting method (Figure 3.12). The equation form for fitting the smooth contours is shown in Equation 3.1.

$$f(x) = y = a + bx + cx^2 + dx^3 \tag{3.1}$$

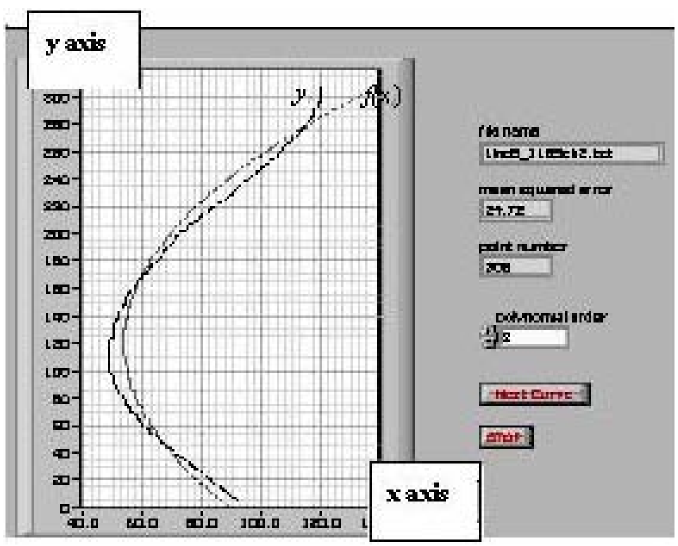
where (x, y) are the Cartesian coordinates of the body contour. The function coefficients are a, b, c, and d.

The degree of non-smoothness can be regarded as the mean square error between the smooth contour and the actual contour points. Equation 3.2 is the summation of squares of distances between the coordinates of actual contour points and smooth contour at the same body height.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}[f(x_i) - y_i]^2 \qquad (3.2)$$

where n is the number of points being investigated along the contour line. y_i and $f(x_i)$ are respectively the y coordinates of the actual body contour points and the smooth body contour, at the i^{th} point on the x-axis.

Figure 3.12 Contour Fitting Program



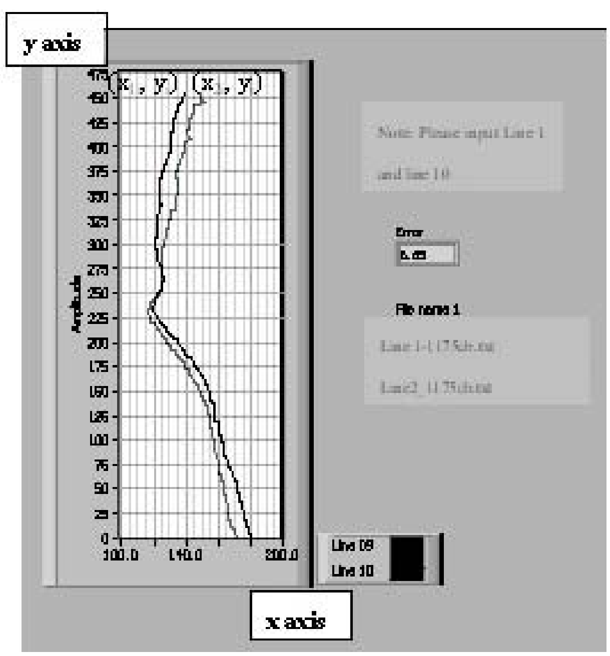
3.6.3 Contour asymmetry – Side contour asymmetry (S_{ca})

The symmetry of the left contour (1) and right contour (2) was analyzed by a "Side contour asymmetry program" as shown in Figure 3.13. The right contour (2) was first mirrored against the centre line, then overlapped the left contour (1). The asymmetry was considered as a summation of squares of distances between *x*-coordinates of side contours (1) and (2), at the same level of height. The asymmetrical level is represented by a mean square error MSE as shown in Equation 3.3.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(x_{1_i} - x_{2_i})^2 \tag{3.3}$$

Where n is the number of points being investigated along the height. x_{1i} and x_{2i} are respectively the x coordinates of the left contour (1) and the right contour (2), at the ith point on the y-axis.

Figure 3.13 Side Contour Asymmetry Program



3.6.4 Contour asymmetry – Breast contour area asymmetry (B_{caa}) and Breast contour asymmetry (B_{cal})

“Breast asymmetry program’ was developed to identify the bilateral asymmetrical degree between the right side and left side of breast contour area and breast contour length. Figure 3.14 shows the overlapping contours of the right breast and mirror left breast contour. The concerned region was outlined between its top edge and bottom edge of the breast. The absolute value of breast contour area difference was calculated by Equation 3.4.

$$\text{Breast contour area difference} = Abs\left[\int_{X_1 0}^{X_1 n} f(x_1)\,dx - \int_{X_2 0}^{X_2 n} f(x_2)\,dx\right] \tag{3.4}$$

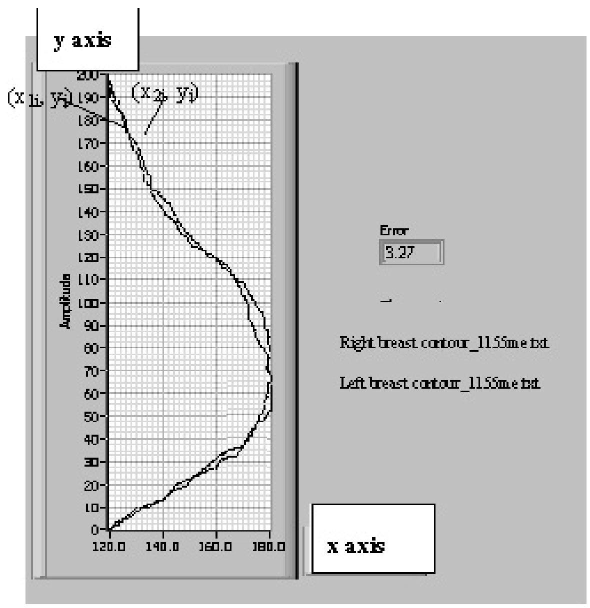
The breast area bound by contour f(x) was calculated by numerical integration, the Composite Trapezium Rule. The sectional area between (x_0, y_0) *to* (x_n, y_n) was splitted into n intervals, where n is the number of points to be investigated along the height. x_{1i} and x_{2i} are respectively the x coordinates of the left breast contour and the right breast contour, at the i^{th} point on the y-axis.

As the side contour asymmetry could be calculated in a similar way, the right breast contour (2) was mirrored and overlapped to the left contour (1). The asymmetry was considered as a summation of squares of distances between the x-coordinates of side contours (1) and (2), at the same level of height. The asymmetrical level is represented by a mean square error MSE as shown in Equation 3.5.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(x_{1i} - x_{2i})^2 \tag{3.5}$$

where n is the number of points being investigated along the height. x_{1i} and x_{2i} are respectively the x coordinates of the left contour and the right contour, at the i[th] point on y-axis.

Figure 3.14 Breast contour area asymmetry program

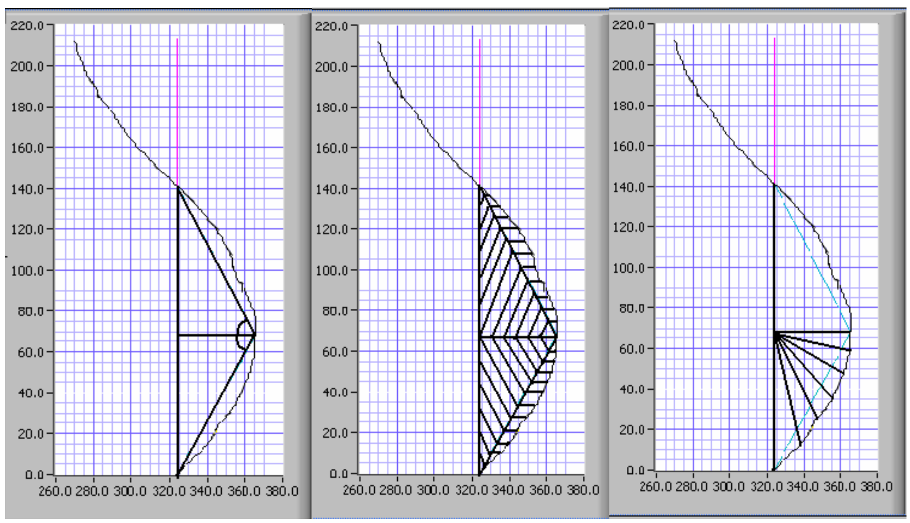


3.6.5 Contour shape

WHR is insufficient to describe the complexity of body shape because women may have different contours shape even if their WHRs are the same. Therefore, body parameters such as height ratios, length ratios, angle ratios, area ratios (the definition of these ratios were comprehensively defined in Methodology Section) which affect contours shape were calculated and the corresponding impacts to body shape attractiveness were examined.

Using our developed “Breast contour shape analysis program” (Figure 3.15), the side breast contour (3) was carefully examined within the region from upper-breast to under-breast. Each contour was divided into top and bottom sections separated by the horizontal breast-line. The vertical line passing through the upper-breast determined the base plane of the breast. The intersection point between this vertical base plane and the horizontal breast line was regarded as the breast centre point.

Figure 3.15 Breast Contour Shape Analysis Program



With simple geometrical calculations, the height, length, angle of both the top and bottom part of contours, as well as the area of both contour sections on right side profile were obtained. In addition, the radius of curvature was measured from the bust centre to the contour line at 0, 15, 30, 45, 60, 75 and 90 degrees (Table 3.7).

Table3.7 Description of breast anthropometric measurements

Body parameters	Description
B_{h1}	Breast: Upper height
B_{h2}	Breast: Lower height
B_l	Breast: Total length
B_{a1}	Breast: Upper angle
B_{a2}	Breast: Lower angle
B_{ca1}	Breast: Upper contour area
B_{ca2}	Breast: Lower contour area
B_{ta1}	Breast: Upper triangle area
B_{ta2}	Breast: Lower triangle area
B_{r15}	Breast: Radius of 15° from bust center to contour line
B_{r30}	Breast: Radius of 30° from bust center to contour line
B_{r45}	Breast: Radius of 45° from bust center to contour line
B_{r60}	Breast: Radius of 60° from bust center to contour line
B_{r75}	Breast: Radius of 75° from bust center to contour line
B_{r90}	Breast: Radius of 90° from bust center to contour line

For the analysis of hip region, it was divided into 6 sections. Using the "Hip contour shape analysis program" (Figure 3.16), the body parameters such as length, angle, area and radius of curvature of each section were determined (Table 3.8).

Figure 3.16 Hip Contour Shape Analysis Program

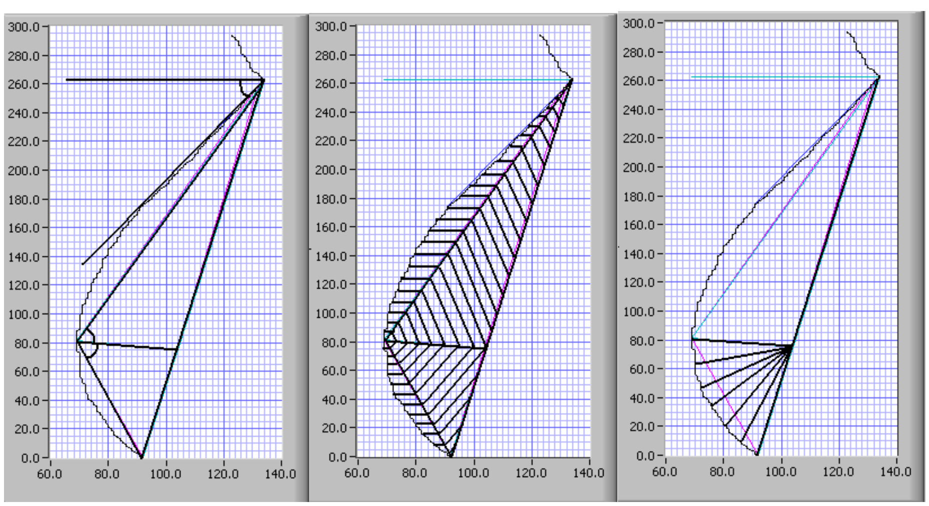


Table 3.8 Description of hip anthropometric measurements

Body parameters	Description
H_{h1}	Hip: Upper height
H_{h2}	Hip: Lower height
H_{l}	Hip: Total length
H_{a1}	Hip: Upper angle
H_{a2}	Hip: Lower angle
H_{a3}	Hip: Outer angle from waist to hip side
H_{ca1}	Hip: Upper contour area
H_{ca2}	Hip: Lower contour area
H_{ta1}	Hip: Upper triangle area
H_{ta2}	Hip: Lower triangle area
H_{r15}	Hip: Radius of 15° from hip center to contour line
H_{r30}	Hip: Radius of 30° from hip center to contour line
H_{r45}	Hip: Radius of 45° from hip center to contour line
H_{r60}	Hip: Radius of 60° from hip center to contour line
H_{r75}	Hip: Radius of 75° from hip center to contour line
H_{r90}	Hip: Radius of 90° from hip center to contour line

Detailed calculations of contour length, angle and area will be explained in the following sections.

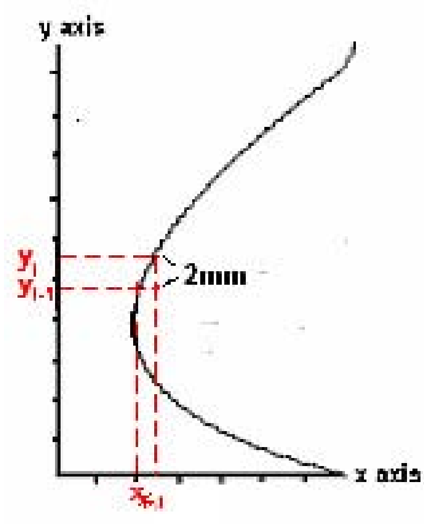
3.6.6 Contour length

In the present work shown in Figure 3.17, each contour line was analyzed by a number of segments with 2mm y-intervals. As presented in Equation 3.6, the entire contour line, *l*, is approximated by the summation of all these small straight line segments between any point (x_i, y_i) and its adjacent point (x_{i+1}, y_{i+1}) on the contour line.

$$\text{Contour line } (l) \approx \sum_{i=1}^{n} \sqrt{(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2} \qquad (3.6)$$

where n is the number of points to be involved along the contour line.

Figure 3.17 Illustration of length calculation on hip contour



3.6.7 Contour angle and distance from breast centre

As illustrated in Figure 3.19, the centre of breast P_o (x_o, y_o) was defined as the local origin (0, 0). In this case, the interior angle of 15° between the x-axis and the line joining P_o and an arbitrary point P_i (x_i, y_i) on the breast contour is defined as the contour angle and it was calculated by the Equation 3.7.

$$\text{Interior angle} = \tan^{-1}\frac{y_i}{x_i} \tag{3.7}$$

Moreover, the distance $\overline{P_iP_o}$ between the breast centre P_0 and that particular point P_i, was evaluated by Equation 3.8.

$$\overline{P_iP_o} = \sqrt{x_i^{\ 2} + y_i^{\ 2}} \tag{3.8}$$

For evaluation purpose, it is required to calculate the distance $\overline{P_\theta P_o}$ between the breast centre and the point, P , on the breast contour with particular contour angle, $_p$. Since the scanned data point may not has a contour angle which coincide with $_p$, the coordinates of P , $(x\ ,\ y\ )$, are obtained by determining the intersection point between a specific small segment line on breast contour and a line passing through the breast centre with a contour angle of $_p$. Then, the distance $\overline{P_\theta P_o}$ can be obtained by using Equation 3.7. An example for evaluating the distance between the breast centre and a point with a contour angle of 15^o is given below.

Let P_{15}, with coordinates (x_{15}, y_{15}), be the point located at a contour angle of 15^o. The line $P_{15}P_o$, joining the points P_{15} *and* P_o, will certainly intersect with the small segment line with end-points P_i (x_i, y_i) and P_{i+1} (x_{i+1}, y_{i+1}) where i>15°>i+1. The line equations of P_iP_{i+1} and $P_{15}P_o$ are shown in Equations 3.9 and 3.10 respectively.

$$\frac{y - y_i}{x - x_i} = \frac{y_{i-1} - y_i}{x_{i-1} - x_i} \tag{3.9}$$

$$\frac{y}{x} = \tan 15° \tag{3.10}$$

By substituting Equation 3.9 into Equation 3.10, the x-coordinate of intersection point P_{15} can be solved by the following equations where x in the above equations becomes x_{15}.

$$\frac{x_{15}\tan 15° - y_i}{x_{15} - x_i} = \frac{y_{i-1} - y_i}{x_{i-1} - x_i}$$

$$x_{15} = \frac{y_i - \dfrac{y_{i-1} - y_i}{x_{i-1} - x_i} x_i}{\tan 15° - \dfrac{y_{i-1} - y_i}{x_{i-1} - x_i}} \tag{3.11}$$

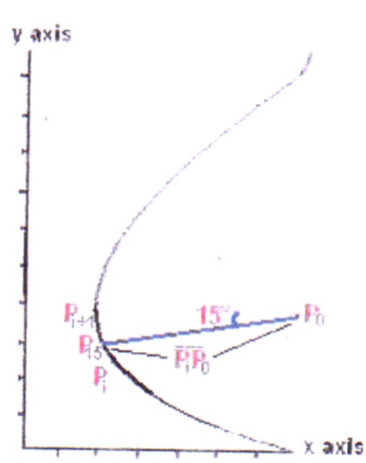
Then, Equation 3.11 is substituted into Equation 3.10, gives y_{15} in Equation 3.12

$$y_{15} = \frac{y_i - \dfrac{y_{i-1} - y_i}{x_{i-1} - x_i} x_i}{\tan 15° - \dfrac{y_{i-1} - y_i}{x_{i-1} - x_i}} \tan 15° \tag{3.12}$$

So, the distance between the breast centre and the point with a contour angle of 15° is shown in Equation 3.13.

$$P_{15}P_o = \sqrt{x_{15}^{\ 2} + y_{15}^{\ 2}} \tag{3.13}$$

Figure 3.18 Illustration of angle calculation on breast contour



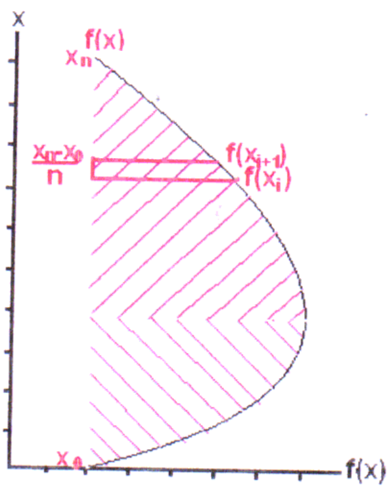
3.6.8 Contour sector area

As shown in Figure 3.19, the sector area bound by contour f(x) was calculated by numerical integration. The sectional area between *(x_0, y_0) to (x_n, y_n)* was splitted into *n* intervals. The area was calculated by the Composite Trapezium Rule as in Equation 3.14.

$$\int_{X0}^{Xn} f(x)d \approx \frac{X_n - X_0}{2n}\{[f(x_0)+f(x_1)]+[f(x_1)+f(x_2)]+\ldots\ldots$$
$$+[f(x_{n-1})+f(x_n)]\}$$

$$\approx \frac{X_n - X_0}{2n}[f(x_0)+f(x_n)+2f(x_1)+2f(x_2)+\ldots.+2f(x_{n-1})] \qquad (3.14)$$

Figure 3.19 Calculation of length, angle and area of breast contour



62 body parameters were categorized as potential parameters to explain average whole body attractiveness ratings. These parameters in Table 3.9 were

represented by symbol of A_1, A_2, S_1 and from B_1 to B_{25}, from H_1 to H_{24}, from R_1 to R_6, from BO_1 to BO_4.

3.7 Subjective body attractiveness assessment on body scanned images

Body attractiveness is the perception of the visual body traits of an individual human person. It can have a significant effect on how people are judged, this leads to the perception that beauty can be equated with goodness in certain ways on visual body[107]. Perception indicates the judges' appreciation or intrinsic value of an object[108].

This study evaluates the effect of functional intimate apparel on the variation of body attractiveness. Subjects were asked to take series of nude and clothed body scanned images. These images were assessed by the subjective physical perception of 40 judges. This section reports the procedure and rating scale in the body attractiveness assessment.

Table 3.9 Classification and description of body parameters for whole body

Description	**Anthropometric measurements**	**Trial functions**	**Body parameters**
Side contour asymmetry	S_{caa}	x	A1
Breast contour area asymmetry	B_{caa}	x	A2
Non-smoothness degree	NS	x	S1
Breast: Height	$B_{h1}+B_{h2}$	x	B_1
Breast: Area	$B_{ca1}+B_{ca2}$	x	B_2
Breast: Total triangle area	$B_{ta1}+B_{ta2}$	x	B_3
Breast: Upper angle	B_{a1}	$Ln[Abs(x-x_{opt})]$	B_4
Breast: Upper angle	B_{a1}	$Abs(x-x_{opt})$	B_5

Breast: Lower angle	B_{a2}	Abs(x-x_{opt})	B_6
Breast: Upper angle/Lower angle	B_{a1}/B_{a2}	Abs(x-x_{opt})	B_7
Breast: Upper area	B_{ca1}	x	B_8
Breast: Lower area	B_{ca2}	x	B_9
Breast: Upper area/Lower area	B_{ca1}/B_{ca2}	x	B_{10}
Breast: Lower area/Total height	$B_{ca2}/(B_{h1}+B_{h2})$	Abs(x-x_{opt})	B_{11}
Breast: Upper triangle area	B_{ta1}	x	B_{12}
Breast: Lower triangle area	B_{ta2}	x	B_{13}
Breast: Upper triangle area/Lower triangle area	B_{ta1}/B_{ta2}	x	B_{14}
Breast: (Upper area/Upper height)/(Lower area/Lower height)	$(B_{ca1}/B_{h1})/(B_{ca2}/B_{h2})$	x	B_{15}
Breast total area/Hip total area	$(B_{ca1}+B_{ca2})/(H_{ca1}+H_{ca2})$	x	B_{16}
Breast triangle area/Hip triangle area	$(B_{ta1}+B_{ta2})/(H_{ta1}+H_{ta2})$	x	B_{17}
Breast: Upper height-lower height	$B_{h1}-B_{h2}$	Abs(x-x_{opt})	B_{18}
Breast: Total length/Total height	$B_l/(B_{h1}+B_{h2})$	Ln[Abs(x-x_{opt})]	B_{19}
Breast: Radius of 15° from bust centre to contour line	B_{r15}/B_l	Abs(x-x_{opt})	B_{20}
Breast: Radius of 30° from bust centre to contour line	B_{r30}/B_l	Abs(x-x_{opt})	B_{21}
Breast: Radius of 45° from bust centre to contour line	B_{r45}/B_l	Abs(x-x_{opt})	B_{22}
Breast: Radius of 60° from bust centre to contour line	B_{r60}/B_l	Abs(x-x_{opt})	B_{23}
Breast: Radius of 75° from bust centre to contour line	B_{r75}/B_l	Abs(x-x_{opt})	B_{24}
Breast: Radius of 90° from bust centre to contour line	B_{r90}/B_l	Abs(x-x_{opt})	B_{25}
Hip: Height	$H_{h1}+H_{h2}$	x	H_1
Hip: Area	$H_{ca1}+H_{ca2}$	x	H_2
Hip:Total triangle area	$H_{ta1}+H_{ta2}$	x	H_3
Hip: Upper angle	H_{a1}	Abs(x-x_{opt})	H_4
Hip: Lower angle	H_{a2}	Abs(x-x_{opt})	H_5
Hip: Upper	H_{a1}/H_{a2}	Abs(x-x_{opt})	H_6

angle/Lower angle			
Hip: Upper area	H_{ca1}	x	H_7
Hip: Lower area	H_{ca2}	x	H_8
Hip: Upper area/Lower area	H_{ca1}/H_{ca2}	$Ln[Abs(x-x_{opt})]$	H_9
Hip: Lower area/Total hip height	$H_{ca2}/(H_{h1}+H_{h2})$	$Abs(x-x_{opt})$	H_{10}
Hip: Upper triangle area	H_{ta1}	x	H_{11}
Hip: Lower triangle area	H_{ta2}	x	H_{12}
Hip: Upper triangle area/Lower triangle area	H_{ta1}/H_{ta2}	x	H_{13}
Hip: (Upper area/Upper height)/(Lower area/Lower height)	$(H_{ca1}/H_{h1})/(H_{ca2}/H_{h2})$	x	H_{14}
Hip: Upper height-lower height	$H_{h1}-H_{h2}$	$Abs(x-x_{opt})$	H_{15}
Hip: Total length/Total height	$H_l/(H_{h1}+H_{h2})$	$Ln[Abs(x-x_{opt})]$	H_{16}
Hip: Radius of 15° from hip centre to contour line	H_{r15}/H_l	$Abs(x-x_{opt})$	H_{17}
Hip: Radius of 30° from hip centre to contour line	H_{r30}/H_l	$Abs(x-x_{opt})$	H_{18}
Hip: Radius of 45° from hip centre to contour line	H_{r45}/H_l	$Abs(x-x_{opt})$	H_{19}
Hip: Radius of 60° from hip centre to contour line	H_{r60}/H_l	$Abs(x-x_{opt})$	H_{20}
Hip: Radius of 75° from hip centre to contour line	H_{r75}/H_l	$Abs(x-x_{opt})$	H_{21}
Hip: Radius of 90° from hip centre to contour line	H_{r90}	$Abs(x-x_{opt})$	H_{22}
Hip: Outer angle from waist to hip side	H_{a3}	$Abs(x-x_{opt})$	H_{23}
Hip: Outer angle/Total area	$H_{a3}/(H_{ca1}+H_{ca2})$	$Ln[Abs(x-x_{opt})]$	H_{24}
Body weight/Height^2 (BMI)	Bo_{wei}/Bo_{hei}	$Abs(x-x_{opt})$	R_1
Body volume/Height^2 (VHI)	Bo_{wei}/Bo_{vol}	$Ln(x)$	R_2
Body volume/Height^2 (VHI)	Bo_{wei}/Bo_{vol}	$Abs(x-x_{opt})$	R_3
Waist girth/Hip girth (WHR)	W_g/H_g	x	R_4
Breast width/Hip width Wacoal Golden Canon Ratio (B:W:Hf)	$(B_w/W_w)/(H_w/W_w)$	x	R_5

Breast depth/Hip depth Wacoal Golden Canon Ratio (B:W:Hs)	$(B_d/W_d)/(H_d/W_d)$	x	R_6
Bone mass	B_m	x	BO_1
Muscle mass	M_m	x	BO_2
Total body water	Bo_{wat}	x	BO_3
Body fat	BO_f	x	BO_4

3.7.1 Profile of assessors

40 professional consultants were invited to be the judges. They have at least two years working experience (mean = 5.3 years) in assessing women's body figures and providing advice to customers on choosing suitable intimate apparel that can beautify the body shape. Therefore, the judges had adequate expertise to give fair and reliable body beauty judgment.

3.7.2 Body stimuli presentation

Different body stimuli presentations can be used for body attractiveness ratings. The line-drawn figures were the most common stimuli used in the work of Singh[109], Furnham *et al.*[110], Tovée *et al.*[111 112]. However, line drawings of unreal body shapes may cause possible flaw. In order to eliminate the bias and potential pitfalls that may occur from using artificial stimuli, Henss[113] tried to present body stimuli in the form of black and white photographs and Tovée *et al.*[114] further used front and side views of photo images. According to Tovée and Cornelissen[115], there was no difference in the perception of female attractiveness between images seen from the front-view and those from both front and side view. In order to provide better quality of the stimuli, Fan[91] used three-dimensional wired-frame stimuli of the female bodies. In this study, the scanned body images were presented in 2D photo profiles (front view and side view) on printed papers and 3D animation profile (with rotation) on projector screen. To generate the 3D images for assessment, the body surface data files were first stored in ASCII format. The data points were then connected with triangles to form 3D meshes. After surface rendering, 3D body model with shadow details was created and the 2D images at different views were captured from the model of different subjects.

A total of 108 body images were visualized in 3D using a VRML (Virtual Reality Modeling Language) format and Maya software program. Each subject image was presented one by one on the screen by a projector and it could be shown at a particular angle for assessment by the viewing software. The image resolution was 436 x 668 pixels and stored as grey color. In order to eliminate the influence of arms and hands on viewing the body image, the arms and hands on images were trimmed. The heads of the images were blurred so that the ratings on body attractiveness were not affected by subjects' facial appearance.

3.7.3 Body attractiveness assessment procedure

At the beginning of the assessment, the judges took a seat in a conference room. The objectives and procedures of the assessment experiments were informed thoroughly. No discussion and interruption was allowed during the judging process. For body attractiveness assessment, several image sheets were prepared for the judges to assess the images, they included:

- 18 naked images of 18 subjects (Figure 3.20)
- Side and front profile images of each subject wearing different bras and girdles (Figure 3.21)
- 6 front images of each subject (Figure 3.22)
- 6 side images of each subject (Figure 3.23)

Apart from the printed materials, the images were also displayed and enlarged on the screen using an overhead projector.

The front and side images of each subjects were randomly displayed on the big screen for judges' review, each image was presented for five minutes.

Figure 3.20 Eighteen subjects' images with nude upper body

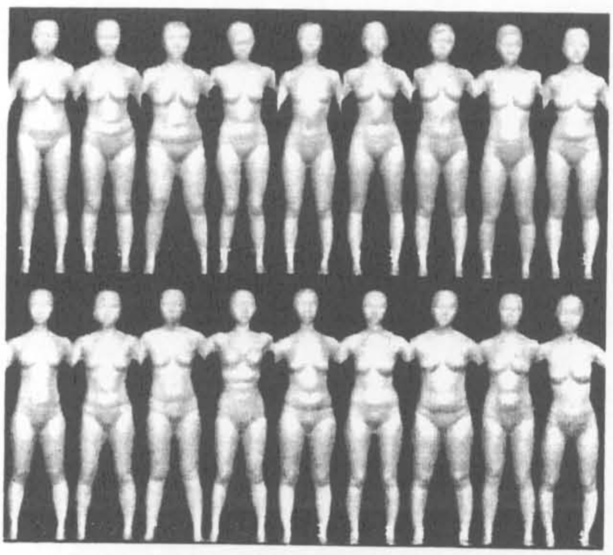


Figure 3.21 Image profile of a subject wearing body shapes

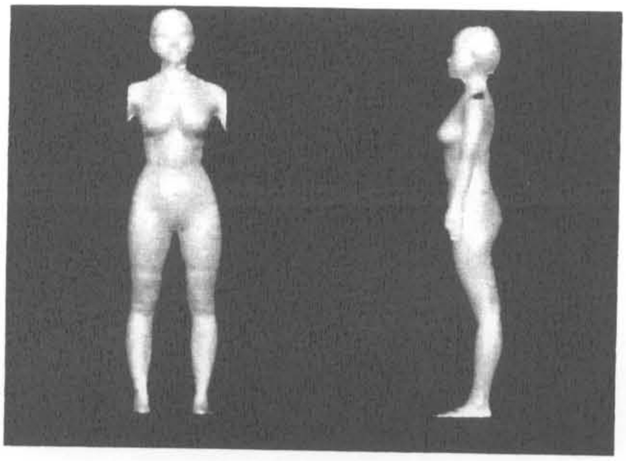


Figure 3.22 Front view of same subject with one nude image and five clothed images

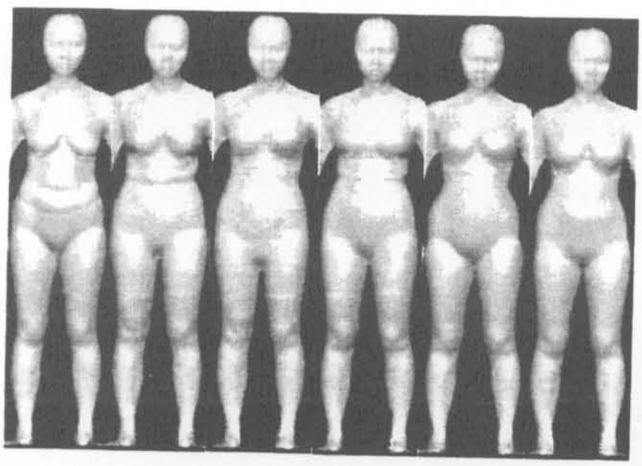
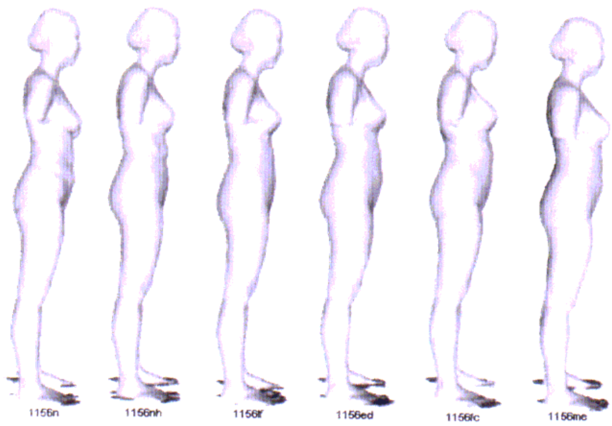


Figure 3.23 Side view of same subject with one nude image and five clothed images



After reviewing all images, judges filled in the questionnaires regarding the body attractiveness ratings in two assessments. (Table 3.10).

3.7.4 First assessment

There are three parts in the first assessment.

In the first part, judges rated the whole body attractiveness of the nude body images of 18 subjects by using 9-point Likert scale in a score ranging from '1' for the least attractive image to '9' for the most attractive image as shown in Table 3.10.

Table 3.10 Overall attractiveness of 18 nude body images

Part one

Look at the 18 nude body images. Based on the body attractiveness of 18 nude body images, please fill in your perception of body attractiveness ratings on each of body image is 9-point Likert scale, 1 being the most unattractive and 9 being the most attractive.

Subject Code	1155n	1156n	1161n	1170n	1172n
Rating					
Subject Code	1173n	1175n	1176n	1177n	1178n
Rating					
Subject Code	1179n	1180n	1181n	1182n	1183n
Rating					
Subject Code	1184n	1185n	1189n	1190n	1192n
Rating					

In the second part, judges assessed the whole body attractiveness on five images of each subject wearing 5 different sets of body shapers (5 clothed images x 18 subjects = 90 images). Each clothed body image was rated by using 9-point Likert scale in a score ranging from '1' for the least attractive image(s) to '9' for the most attractive image as shown in Table 3.11.

Table 3.11 Overall attractiveness of 108 body images

Part two

Look at the six images from each subject. Based on the body attractiveness ratings given for nude body images, please fill the body attractiveness ratings on the rest of five images for each subject. The rating scale is 9-point Likert scale, 1 being the most unattractive and 9 being the most attractive.

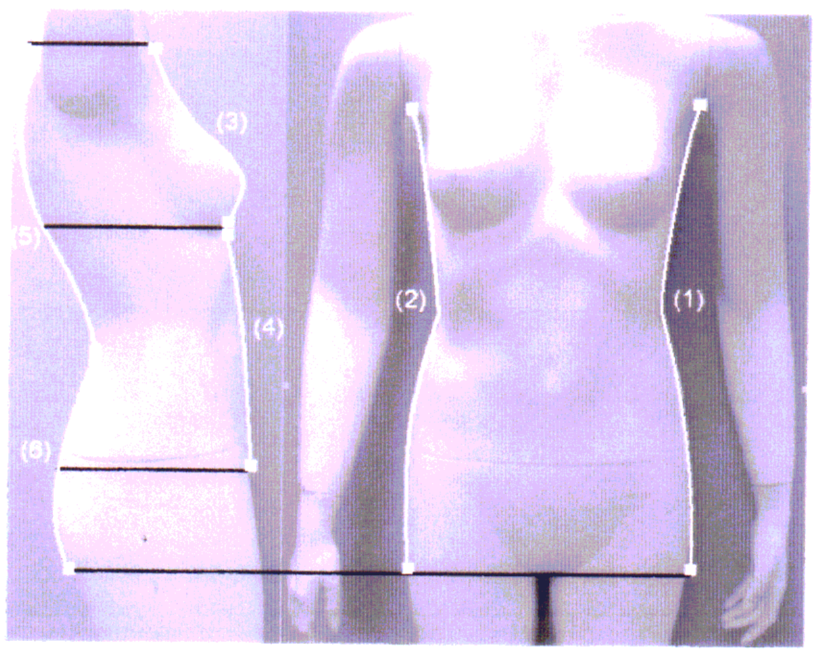
Subject Code	1155n	1155nh	1155lf	1155ed	1155fc	1155me
Rating						
Subject Code	1156n	1156nh	1156lf	1156ed	1156fc	1156me
Rating						
Subject Code	1161n	1161bh	1161df	1161ed	1161kc	1161me
Rating						
Subject Code	1170n	1170aa	1170cb	1170id	1170mc	1170ne
Rating						
Subject Code	1172n	1172fa	1172lb	1172md	1172nc	1172qe
Rating						
Subject Code	1173n	1173aa	1173cb	1173id	1173mc	1173ne
Rating						
Subject Code	1175n	1175aa	1175cb	1175dd	1175ic	1175ne
Rating						
Subject Code	1176n	1176aa	1176cb	1176dd	1176ic	1176ne
Rating						
Subject Code	1178n	1178fa	1178lb	1178md	1178nc	1178qe
Rating						
Subject Code	1179n	1179aa	1179cb	1179dd	1179ic	1179ne
Rating						
Subject Code	1180n	1180aa	1180cb	1180dd	1180ic	1180ne
Rating						
Subject Code	1181n	1181bh	1181ef	1181fd	1181gc	1181ke
Rating						
Subject Code	1182n	1182fa	1182lb	1182md	1182nc	1182qe
Rating						
Subject Code	1183n	1183bh	1183ef	1183fd	1183gc	1183ke
Rating						
Subject Code	1184n	1184bh	1184ff	1184kd	1184mc	1184ne
Rating						
Subject Code	1189n	1189ah	1189cf	1189gg	1189ic	1189mb
Rating						
Subject Code	1190n	1190eh	1190hf	1190kd	1190pc	1190qe
Rating						
Subject Code	1192n	1192ba	1192fb	1192kd	1192mc	1192ne
Rating						

In the third part, judges reviewed the body contour as shown in Figure 3.12, and gave ratings on the significance of each contour segment in affecting the whole body attractiveness. The rating ranged from '1' being the most significant to '9' being the least significant as shown in Table 3.12.

Table 3.12 Identify attractiveness significance of body contour segments

Part three

According to the six body contours identifying from the left hand side picture, please fill in the rating to represent the influence of the individual contour beauty on whole body attractiveness. The rating scale is 9-point Likert scale, 1 being the least significant and 9 being the most significant.



Contour	Rating
Contour (1)	
Contour (2)	
Contour (3)	
Contour (4)	
Contour (5)	
Contour (6)	

After collected the assessment forms and finished the analysis on which contour segment' attractiveness is most significant to affect whole body attractiveness, the second body attractiveness assessment was carried out.

3.7.5 Second assessment

After the most important contour segment was determined by the judges, the same group of judges were asked to rate the attractiveness of that particular contour segment on all 108 subject images using a 9-point Likert scale from '1' for the least attractive contour segment to '9' for the most attractive contour segment as shown in Table 3.13.

Table 3.13 Second Assessment Form – Attractiveness of key contour segment on 108 images

Please look at the images and fill in the body contour attractiveness ratings on all images for each subject. The rating scale is 9-point Likert scale, 1 being the most unattractive and 9 being the most attractive.

Subject Code	1155n	1155nh	1155lf	1155ed	1155fc	1155me
Rating						
Subject Code	1156n	1156nh	1156lf	1156ed	1156fc	1156me
Rating						
Subject Code	1161n	1161bh	1161df	1161ed	1161kc	1161me
Rating						
Subject Code	1170n	1170aa	1170cb	1170id	1170mc	1170ne
Rating						
Subject Code	1172n	1172fa	1172lb	1172md	1172nc	1172qe
Rating						
Subject Code	1173n	1173aa	1173cb	1173id	1173mc	1173ne
Rating						
Subject Code	1175n	1175aa	1175cb	1175dd	1175ic	1175ne
Rating						
Subject Code	1176n	1176aa	1176cb	1176dd	1176ic	1176ne
Rating						
Subject Code	1178n	1178fa	1178lb	1178md	1178nc	1178qe
Rating						
Subject Code	1179n	1179aa	1179cb	1179dd	1179ic	1179ne
Rating						

Subject Code	1180n	1180aa	1180cb	1180dd	1180ic	1180ne
Rating						
Subject Code	1181n	1181bh	1181ef	1181fd	1181gc	1181ke
Rating						
Subject Code	1182n	1182fa	1182lb	1182md	1182nc	1182qe
Rating						
Subject Code	1183n	1183bh	1183ef	1183fd	1183gc	1183ke
Rating						
Subject Code	1184n	1184bh	1184ff	1184kd	1184mc	1184ne
Rating						
Subject Code	1189n	1189ah	1189cf	1189gg	1189ic	1189mb
Rating						
Subject Code	1190n	1190eh	1190hf	1190kd	1190pc	1190qe
Rating						
Subject Code	1192n	1192ba	1192fb	1192kd	1192mc	1192ne
Rating						

3.8 Statistical analysis for predicting whole body attractiveness

3.8.1 Paired t-Test on the clothed effect of body shapers

A paired sample t-test was used to determine whether there was a significant difference between the average values of the attractiveness ratings of scanned image in two different conditions - one was nude body image and the other were clothed images. The usual null hypothesis is that the difference in the mean values between pairs of data set is zero:

H_0: $\mu_n = \mu_c$

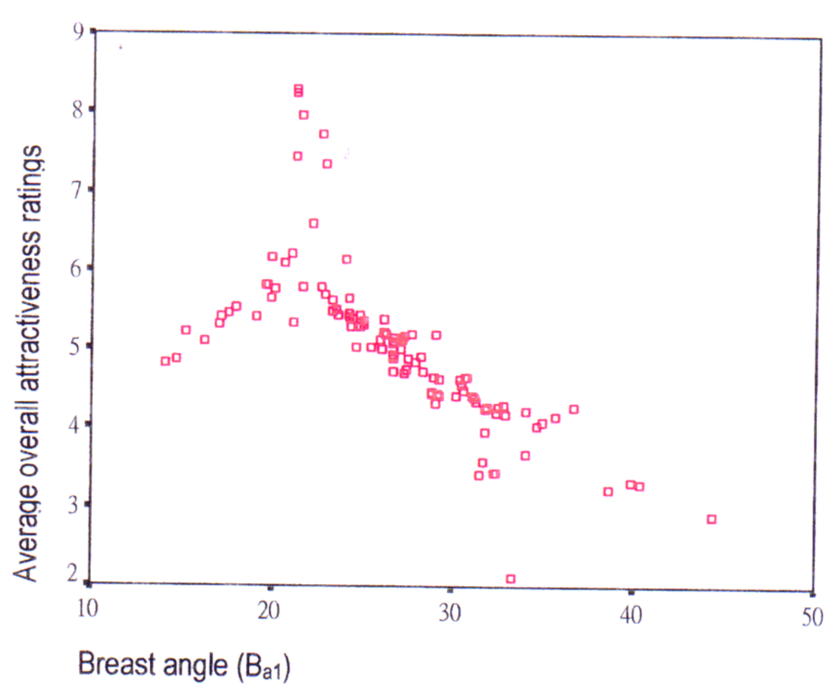
H_1: $\mu_n \neq \mu_c$

where μ_n is the population mean of nude body images, μ_c is the population mean of clothed images. Probability (P) value smaller than 0.05 means that body attractiveness ratings given to scanned images with and without wearing body shaper are significantly different.

3.8.2 Scatterplot and non-linear data pattern

Prior to the implementation of any statistical analysis for determining the relationship between body parameters and attractiveness rating, scatterplots were used to interpret the data trend. Figure 3.24 shows that the AWAR (data y) has a tendency to incline to an increase of upper breast angle, B_{a1} (data x), rapidly towards the highest attractiveness ratings and then decline with an increase of upper breast angle (B_{a1}), after the highest rating. This kind of non-linear data trend cannot be presented by any individual polynomial functions. Therefore, each of data x was converted into absolute deviations from a specific x value where gave the highest rating and it was defined as the optimum data (x_{opt}).

Figure 3.24 Scatterplot between AWAR (overall attractiveness) and original upper breast angle (B_{a1}) data

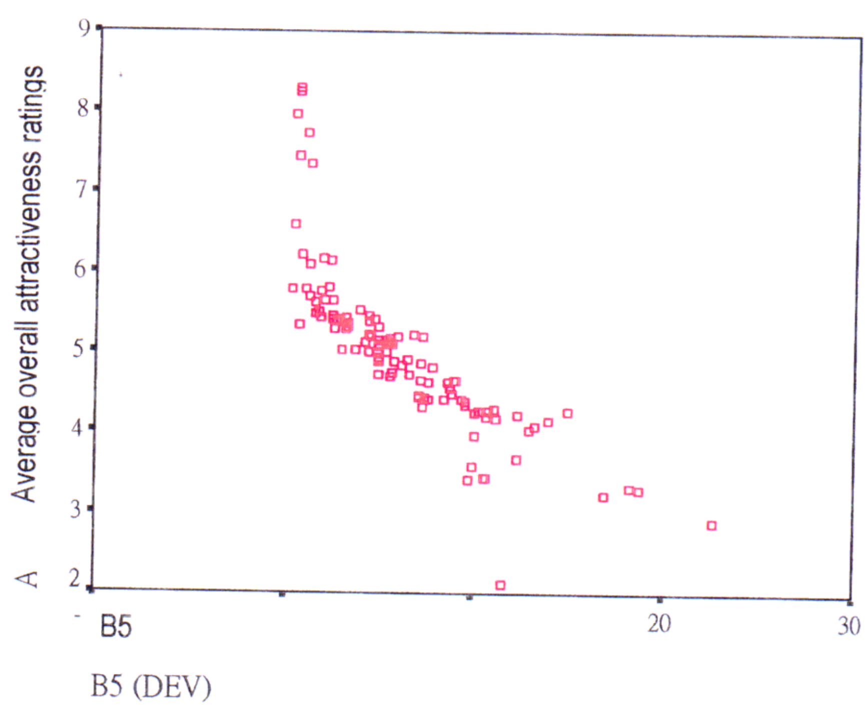


The average of upper breast angle (B_{a1}) that got attractiveness ratings of 7 or above was regarded as 'optimum upper breast angle' (x_{opt}). Deducting the original data by the optimum data gives the absolute deviations (B5) by Equation 3.15. These deviations plotted with average whole body attractiveness ratings are shown in Figure 3.25 that illustrates a non-linear relationship.

$$B5 = \text{Abs}\,(x - x_{opt}) = |x - x_{opt}| \tag{3.15}$$

where x is the raw data average of upper breast angle (B_{a1}), and x_{opt} is the optimal upper breast angle that got attractiveness ratings of 7 or above.

Figure 3.25 Scatterplot between AWAR (overall attractiveness) and B5 (upper breast angle) in absolute deviation from optimum upper breast angle.



The relationship between AWAR and $B_l/(B_{h1}+B_{h2})$ (breast total length/total height) is shown in Figure 3.26 In order to identify the relationship between average overall attractiveness ratings and $B_l/(B_{h1}+B_{h2})$ (breast total length/total height) by linear relationship, the natural logarithm function was taken on the absolute deviation from the original data (x) to optimum data (x_{opt}) as shown in Figure 3.27.

$$B19 = \ln[\mathrm{Abs}(x-x_{opt})] = \ln|x-x_{opt}| \tag{3.16}$$

where x is any one of parameter data, and x_{opt} is the data of body parameter with attractiveness ratings from 7 to 9.

Figure 3.26 Scatterplot between AWAR and $B_l/(B_{h1}+B_{h2})$ original data

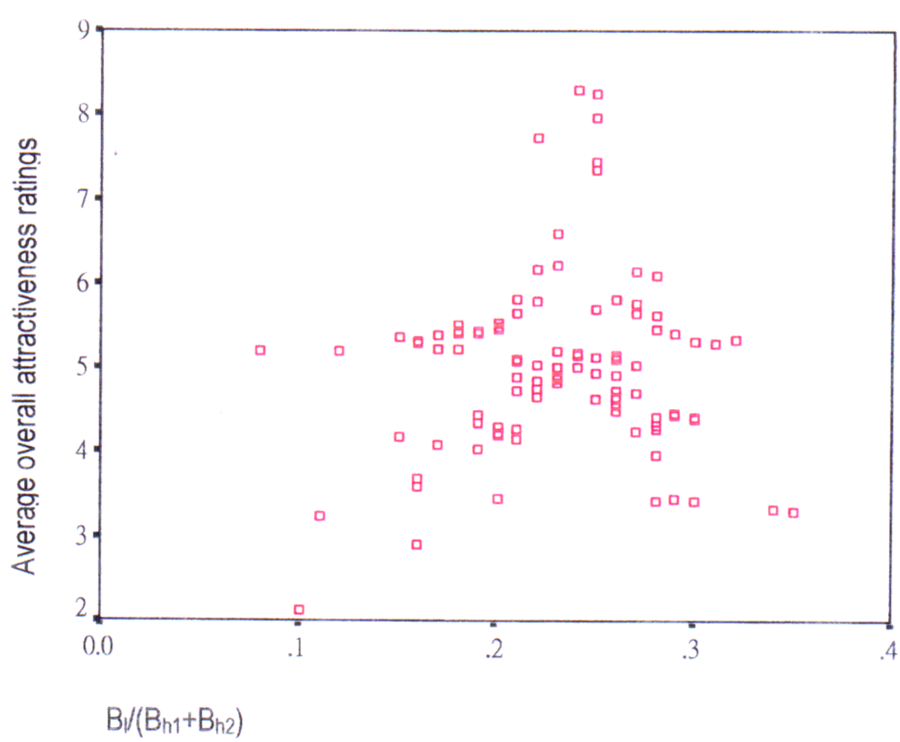
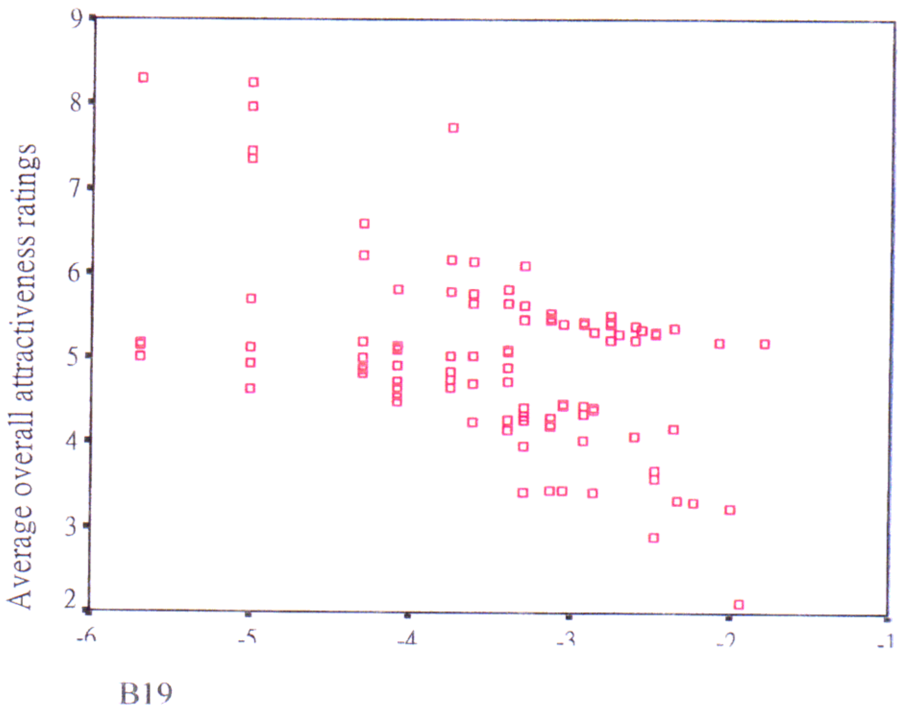


Figure 3.27 Scatterplot between AWAR and B19 in natural logarithm of the absolute deviation from optimum



3.8.3 Stepwise multiple regression analysis

The 62 body parameters indicated in Table 3.9 were considered as potential parameters that may explain the body attractiveness. Stepwise Multiple Regression analysis was used to identify the best body parameters as the body attractiveness predictors of statistical significance. Stepwise procedure is a variable selection method. The independent parameter, which is the most correlated to average attractiveness ratings, is selected for entry into the prediction equation. The second independent parameter which is the second most correlated to attractiveness ratings becomes the second parameter and so on. The criterion for entry is that either F value is greater than a threshold value or the partial correlation is the highest one. This variable selection procedure transacts iteratively until the selection of additional independent parameter does not increase the R-square by significant amount, where significance level was set at 0.05.

Stepwise Multiple Regression is accurate if the data variables fulfill two important criteria. First, a bivariate scatter plot of variables is examined for linearity. In case not, the function will be transformed to a linear one before performing the multiple regression analysis. An example is the transformation from the non-linear plot in Figure 3.24 to a linear relationship in 3.25. Second, multivariate normality is ensured. To ensure that the dependent variables are normally distributed for each combination of independent variables, histogram of standardized residuals and normal probability plot were checked. In case not, the variables in abnormal distribution would be ignored before doing multiple regression analysis. Due to the high correlation coefficients found from the multiple regression models with 0.05 significance level and the data scatter plots, it was believed that the statistical analysis results were reliable and accurate with normal distributed data.

The influences of body parameters' component indices on the body attractiveness were analyzed using the stepwise variable selection method before multiple linear regressions. The prediction Model is shown in Equation 3.17.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots. b_kX_k \tag{3.17}$$

where Y is the predicted average overall attractiveness ratings, a is the predicted value for average overall attractiveness ratings when every independent variable (X) is 0. b_1, b_2, b_3 ....b_k are the regression coefficients of independent body parameters X_1, X_2, X_3...X_k respectively. They reflect the effect of each body parameter on average overall attractiveness ratings when holding all other body parameters variables constant.

3.8.4 Significance test

The ratings given to six contour segments of each body image (from 1 represents the least significant contour to 9 represents the most significant contour) indicate how the whole body attractiveness is influenced by which contour segment beauty. The results reveal which part of body contours that should be focused on and which part of body contour can be ignored. The attributes of the most significant contour are then identified using ANOVA and Multiple Regression analysis.

ANOVA is a general technique that can be used to test the hypothesis that the means among two or more groups are equal, under the assumption that the sampled populations are normally distributed. In this project, One-way ANOVA was used to determine if any significant difference exists in attractiveness rating given to the two key body contour segments and the attractiveness rating given to the whole body under reviewing the same image. The H_o and H_1 hypotheses are listed below.

H_0: $\mu_{k1} = \mu_{k2} = \mu_{WB}$

H_1: At least one of μ is different (where μ represents $\mu_{k1}, \mu_{k2}, \mu_{WB}$)

3.8.5 Absolute value of change

Once the key contour segment is identified, it is possible to adjust the contour parameters with an aim to achieve optimal body contour that enhance the whole body attractiveness.

The change of contour attractiveness ratings after wearing body shapers was presented by a difference of the contour attractiveness ratings on clothed body images ($ACAR_c$) and the nude body images ($ACAR_n$), as shown in Equation 3.18.

$$\text{Change of contour attractiveness} = |ACAR_c - ACAR_n| \quad (3.18)$$

where $ACAR_c$ is average contour attractiveness ratings of one subject's clothed image and $ACAR_n$ is average contour attractiveness ratings of one subject's nude image.

The corresponding change in contour parameters after wearing body shapers were represented by deviations from the clothed body images (cx_c) to nude body image (cx_n), as shown in Equation 3.19. It helps determine the contour parameters that significantly influence the change in average contour attractiveness ratings.

$$\text{Absolute value of the change of contour parameter} = (|cx_c - cx_n|) \tag{3.19}$$

where cx_c is contour parameter from one subject's image with wearing body shaper and cx_n is contour parameter from one subject's image with nude body.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results of Paired t-Test on the clothed effect

In this study, paired t-test was used to investigate whether there was a significant difference of the average body attractiveness rating between the ones wearing body shapers and nude bodies. For all 18 subjects, attractiveness ratings of five clothed images of each subject were compared with her own nude image and hence there were 18 subjects × 5 clothed images = 90 pairs of data in total.

As shown in Table 4.1, the mean average attractiveness ratings (ARs) given to the 90 clothed images of 18 subjects is 6.05 while that of naked bodies is 4.79. It shows that the body figures with body shapers are more attractive and have an increase of attractiveness ratings by 1.26 (i.e. 6.05 – 4.79) in average. Furthermore, it can also be concluded from Table 4.2 that body shapers make a significant enhancement in the perceived body attractiveness as $p < 0.05$ with 89 degree of freedom.

Table 4.1 Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ARs - Unclothed	4.79	90	1.818	0.192
	ARs - Clothed	6.05	90	1.5824	0.1668

Table 4.2 Paired Sample Test

		Degree of freedom	Sig.
Pair 1	ARs - Unclothed & ARs - Clothed	89	0.000

In Table 4.3, the correlation coefficient of attractiveness ratings between clothed and naked images is 0.869 with $p < 0.05$. It means that subjects who were rated as more attractive in naked would also be considered as more attractive than other subjects in body shapers, vice versa.

Table 4.3 Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	ARs - Unclothed & ARs - Clothed	90	0.869	0.001

4.2 Correlation between Body Attractiveness (AWAR and ANAR) and different body ratios

To examine whether the body ratios such as Wacoal Canon Ratio, BMI, WHR, VHI, were able to predict body attractiveness, correlations between 18 nude body attractiveness ratings (ANAR) and the subjects' body ratios were performed and the results are shown in Table 4.4.

Table 4.4 Correlations coefficient between ANAR and five body ratios on 18 nude images

	ANAR	BMI	VHI	WHR	Wacoal Golden Canon Ratio ($B:W:H_f$)	Wacoal Golden Canon Ratio ($B:W:H_s$)
ANAR	1					
BMI	-0.736	1				
VHI	-0.738	0.961	1			
WHR	-0.363	0.240	0.339	1		
Wacoal Golden Canon Ratio ($B:W:H_f$)	0.504	-0.610	-0.503	0.283	1	
Wacoal Golden Canon Ratio ($B:W:H_s$)	0.454	-0.397	-0.374	0.189	0.408	1

Both BMI (r = -0.736) and VHI (r = -0.738) have significant linear relationships with the nude body attractiveness. There is also high correlation between BMI and VHI (r = 0.96). However, WHR, Wacoal Golden Canon ratios, ($B:W:H_f$) and ($B:W:H_s$) are not significantly related to the nude body attractiveness ratings (ANAR) and their correlation coefficients (r) are -0.363, 0.504 and 0.454 respectively.

To further evaluate the nude body images and clothed images at the same time, a total of 108 images [18 subjects × (5 clothed images + 1 nude image) = 108 images] were taken into consideration in another correlation. The ability of body ratios to explain the average whole body attractiveness ratings (AWAR) deteriorates when considering all 108 images with and without body shapers. Based on these results, the correlation coefficient between VHI and AWAR is -0.521 whereas the correlation coefficient between BMI and AWAR is -0.416. VHI has the strongest correlation with the average whole body attractiveness ratings (AWAR) because the body shapers have tummy control or hip-up function that lead to a change in body volume, rather than a change in weight. As shown in Table 4.5, the values are relatively low when compared with that for ANAR in Table 4.4. It is because the perceived body attractiveness between clothed images and naked body's image of an individual subject varies from image to image but the subject's body weight, body height and simple body proportion data in the statistical analysis for this particular set of images remain the same. Therefore, VHI is more practical than BMI to interpret the average whole body attractiveness ratings with clothing. Besides, the weak correlation of WHR, Wacoal Golden Canon Ratio ($B:W:H_f$) and Wacoal Golden Canon Ratio ($B:W:H_s$), which are respectively -0.278, 0.390 and 0.387, reveals the ratios cannot significantly distinguish the difference of body attractiveness ratings amongst both clothed and nude body images of different subjects.

Table 4.5 Correlations coefficient between AWAR and five body ratios for 108 nude and clothed images

	AWAR	BMI	VHI	WHR	Wacoal Golden Canon Ratio (B:W:Hf)	Wacoal Golden Canon Ratio (B:W:H_s)
AWAR	1					
BMI	-0.416	1				
VHI	-0.521	0.832	1			
WHR	-0.278	0.203	0.232	1		
Wacoal Golden Canon Ratio (B:W:H_f)	0.390	-0.524	-0.462	0.252	1	
Wacoal Golden Canon Ratio (B:W:H_s)	0.387	-0.322	-0.348	0.133	0.337	1

Overall speaking, body ratios are not good enough to predict body attractiveness of subjects wearing body shapers. In order to investigate the visual predictors that account for body attractiveness, detailed study of the body parameters, body proportion and contour traits were identified in the following sections.

4.3 Stepwise Multiple Regression Analysis between whole body attractiveness and individual body parameters

In this project, Multiple Regression was used to test the effects of body parameters (predictors) on average whole body attractiveness ratings (criterion). In case of a multi-variable problem, the regression equation is arrived at in a sequence of multiple linear regression equations, in a stepwise manner. At each step of the sequence, one parameter is added to the regression equation. The variable added is the one that makes the greatest reduction in the error sum of squares of the sample data. Equivalently it is the parameter that when added, provides the greatest increase in the F value. Parameters, not having a significant correlation with the dependent average whole body attractiveness, are those whose additions do not increase the F value and are not featured in the regression equation.

A multiple regression analysis was used to study the coefficient of determination (r^2) among 108 ratings on body attractiveness, and the 62 body parameters in Table 3.9 as well as the ratios, proportions and contour traits (Contour smoothness, contour symmetry, contour shape) of the 18 subjects. 5 body parameters which had high correlations with the attractiveness ratings are given in Table 4.6, i.e. B_5, H_{10}, H_{20}, B_{20} and B_{19}. The Multiple regression equation in Model 5 that most significantly predicted the body attractiveness was $5.746\text{-}0.640B_5\text{-}0.021H_{10}\text{-}0.097H_{20}\text{-}5.496B_{20}\text{-}0.73B_{19}$ with the highest coefficient of determination ($R^2 = 0.932$, $p < 0.05$). There was 93.2% of variation in whole body attractiveness ratings being explained by the variation of these five independent parameters.

Table 4.6 Equations of AWAR deriving by body parameters from MLR

Model	Equation from MLR	Coefficient of determination (R^2)
1	$6.505\text{-}1.019B_5$	0.894
2	$6.476\text{-}0.807B_5\text{-}0.042H_{10}$	0.919
3	$6.079\text{-}0.715B_5\text{-}0.041H_{10}\text{-}0.088H_{20}$	0.924
4	$6.003\text{-}0.658B_5\text{-}0.022H_{10}\text{-}0.106H_{20}\text{-}5.299B_{20}$	0.929
5	$5.746\text{-}0.640B_5\text{-}0.021H_{10}\text{-}0.097H_{20}\text{-}5.496B_{20}\text{-}0.73B_{19}$	0.932

According to Table 3.9, the parameters contributed to the Models are:

B_5 = Absolute deviation from optimal Breast: upper angle B_{a1},

H_{10} = Absolute deviation from optimal Hip: lower area/Total hip height

H_{20} = Absolute deviation from optimal Ratio of Hip: Radius of 60° from hip centre to contour line = H_{r60}/H_l,

B_{20} = Absolute deviation from optimal Ratio of Breast: Radius of 15° from bust centre to contour line and

B_{19} = Natural log of absolute deviation from optimal Breast length/Breast height

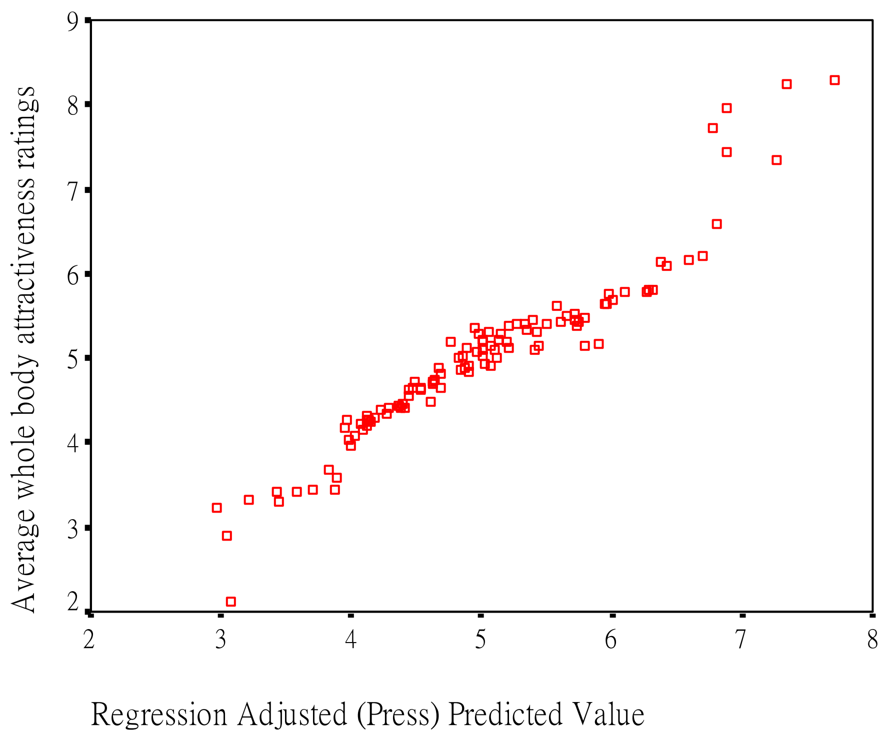
Among the five independent parameters, relatively high coefficient of determination (R^2) was obtained from the upper breast angle B_5. It explains 89.4% of average whole body attractiveness ratings. According to the collected data, the optimal breast upper angle (B_5) was 21.72°, which obtained the highest attractiveness rating on the subject's image. In this project, the breast upper angle was defined as the proportion of upper breast height and upper breast length. Based on the results in Table 4.6, the proportion of upper breast height and upper breast length was the most important criteria to determine the subjects' whole body attractiveness as this proportion directly affected the value of breast upper angle.

The parameter H_{10}, Hip: lower area/Total hip height, is the second most significant body parameter to affect the AWAR. The subject's image, which obtained the highest attractiveness rating, has its H_{10} equals to 47.01. The ratio of lower hip area in side profile and total hip height highly affected the whole body attractiveness. Too large or too small of lower hip area under certain hip height may cause lower hip shape looks too protruding or too flatted. On the other hand, too long or too short in hip height under certain lower hip area leaded to a falling or a swollen hip shape.

H_{20} and B_{20} portrayed the delicate breast and hip contour shape. The optimal ratio of Hip: Radius of 60° from hip centre to contour line (H_{20}) was 1.21. This reveals that the hip radius at 60° should be slightly longer than the hip length. When a body has this optimum body parameter, the lower hip shape would be in vertical oval shape whereas the optimal ratio of Breast: Radius of 15° from bust centre to contour line (B_{20}) was 0.99, which means judges prefer rounded lower breast contour shape. In addition, the best ratio of Breast length/Breast height (B_{19}) was 0.24, which reveals that the whole body attractiveness also depends on the extension of breast length under certain breast height.

Based on the predictive equation in Model 5, Figure 4.1 shows a linear relationship between the average whole body attractiveness ratings and the predicted body attractiveness ratings projected from the regression Model. It is confirmed that the parameters contributed in the regression Model has strong explanatory power to predict the attractiveness ratings.

Figure 4.1 Comparison between predictive average whole body attractiveness ratings and actual average whole body attractiveness ratings from multiple linear regressions



After reviewing the scatterplots of these five body parameters, which contributed to the Regression Model 5, it was found that B_5, B_{20} and B_{19} showed linear relationship with the average whole body attractiveness ratings. On the other hand as shown in Figures 4.2 and 4.3, the attractiveness ratings were influenced by the parameters of H_{10} and B_{20} when the average whole body attractiveness ratings equal or less than 5.5. There is no effect at all for predicting the average whole body attractiveness ratings larger than 5.5.

More specifically when the ratings were less than 5.5, the scatterplots revealed an adverse effect of the deviation from the optimum value of body parameters on the average whole body attractiveness ratings. The body images are perceived more attractive (with ratings from 5.5 to 9) when the deviation from the optimum value of body parameter is smaller. It is interesting to find that the judges rated the body shapes differently above or below a rating of 5.5. Therefore, the data analysis was divided into two groups: data with rating ≤ 5.5 and data with rating > 5.5. Multiple regression analysis was performed for each data set in order to find out if there is any difference in the body parameters contributed in the two multiple regression equations.

Figure 4.2 Scatterplot between Average whole body attractiveness ratings and H_{10}

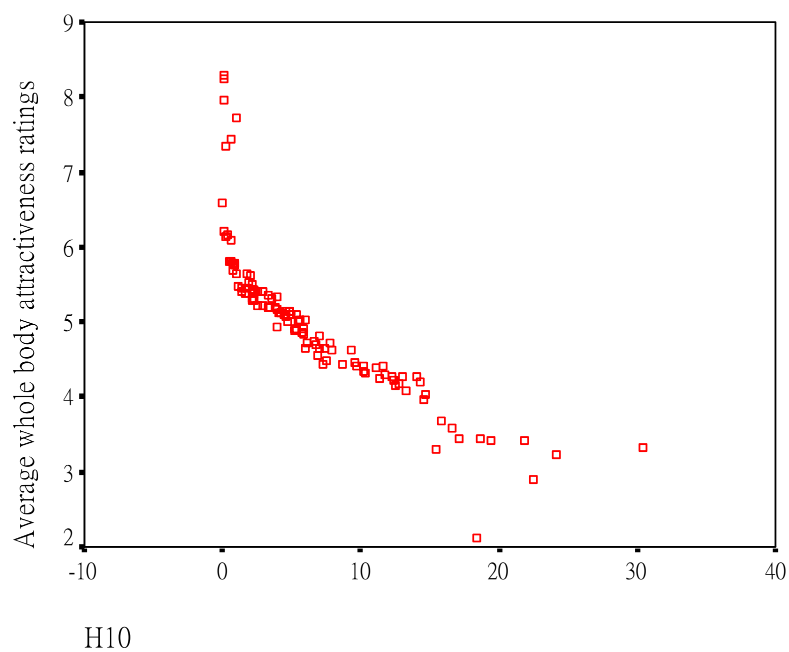
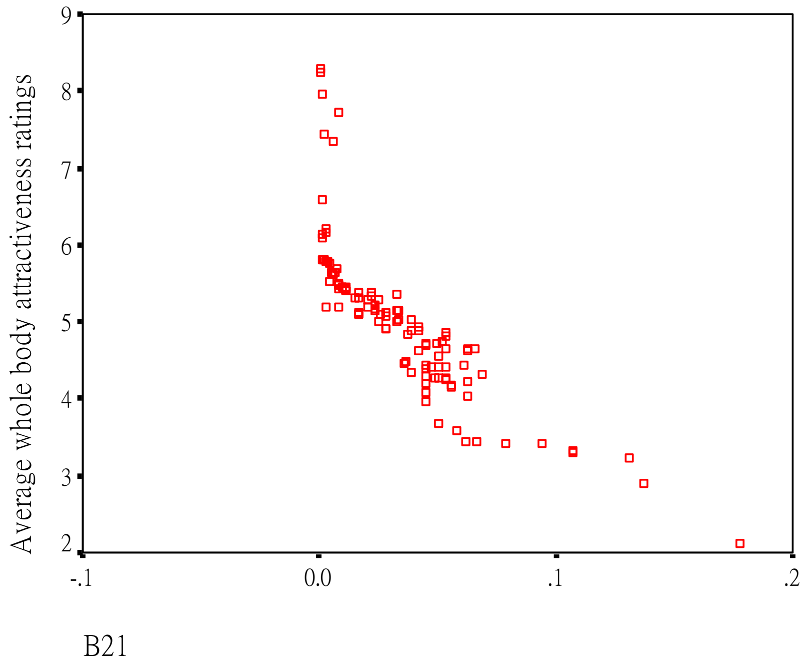


Figure 4.3 Scatterplot between Average whole body attractiveness ratings and B_{20}



4.3.1 Multiple Regression for attractiveness ratings ≤ 5.5

When only the data with AWAR ≤ 5.5 was analyzed, the new multiple regression equations are shown in Table 4.7.

Table 4.7 Equations of AWAR that are equal or below 5.5 deriving by body parameters from MLR

Model	Equation from MLR	Correlation coefficient (R^2)
1	$5.847-0.163B_5$	0.922
2	$5.778-0.102B_5-0.046H_{10}$	0.954
3	$5.803-0.065B_5-0.038H_{10}-0.090H_{23}$	0.969
4	$5.823-0.064B_5-0.034H_{10}-0.083H_{23}-1.285H_{19}$	0.973
5	$5.810-0.051B_5-0.031H_{10}-0.070H_{23}-1.378H_{19}-3.245B_{20}$	0.977
6	$5.841-0.052B_5-0.030H_{10}-0.069H_{23}-1.324H_{19}-3.285B_{20}-0.034R_3$	0.978

B_5 = Absolute deviation from optimal Breast: upper angle

H_{10} = Absolute deviation from optimal Hip: lower area/Total hip height

H_{23} = Absolute deviation from optimal Hip: Outer angle from waist to hip side

H_{19} = Absolute deviation from optimal Hip: Radius of 45^o from hip centre to contour line

B_{20} = Absolute deviation from optimal Breast: Radius of 15^o from bust centre to contour line

R_3 = Absolute deviation from optimal Body volume/Height^2 (VHI)

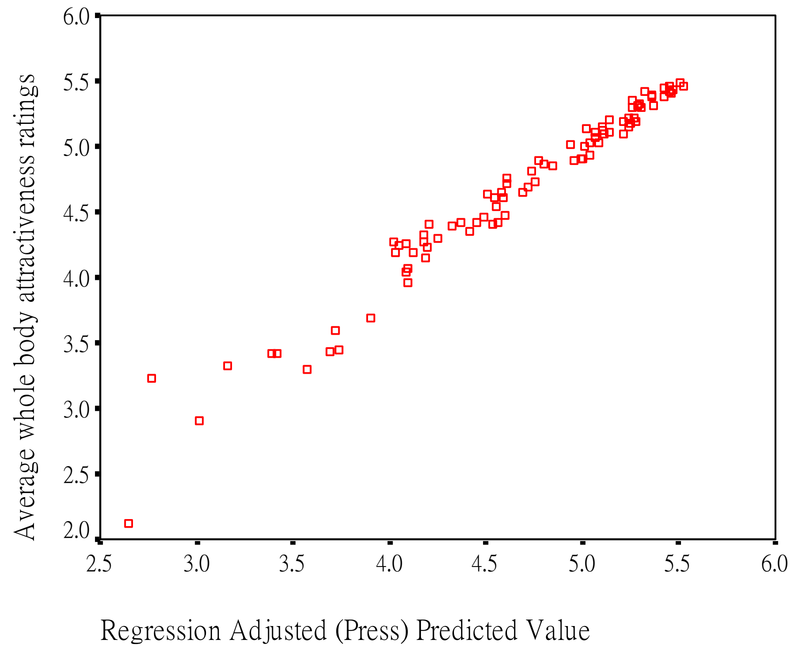
In Table 4.7, the multiple regression equation which has the highest coefficient of determination r^2 = 0.978 is contributed by all 6 parameters. B_5 and H_{10} are still the two main predictors and they explain 95.4% of average whole body attractiveness ratings (from 1 to 5.5). That means judges perceived body attractiveness mainly on the protruding degree of upper breast and lower hip in the side profile. Furthermore, it can be observed from the Model 6 that the whole body attractiveness is equal to a constant value of 5.841 subtracted by all six products of body parameters × coefficients. As all these parameters are the aabsolute deviations from its own optimum value. That means the smaller the absolute deviation from the optimum value, the greater the whole body attractiveness rating and the ratings are closer to the highest rating of 5.841. It seems that judges gave an instant impression on each subject' images, say, a certain whole attractiveness rating of 5.841 and then tended to deduct ratings on those images deviated from the 6 significant body parameters included in Model 6.

Apart from parameters B_5 and H_{10}, contributing parameter of H_{23} is also included in the Model 6 and it describes the shape of upper hip. The best protruding angle of upper hip from waist to hip in the side profile is 68^o. H_{19} refers to deviation from the optimal ratio of Hip: Radius of 45^o from hip centre to contour line, which is 1.07. B_{20} is the deviation from the optimal ratio of Breast: Radius of 15^o from bust centre to contour line, which is 0.99. The contribution of these parameters to the Multiple Regression equation reflected that contour shapes of hip and breast also determine the average whole body attractiveness ratings (from 1 to 5.5) and the rounded lower breast is preferred.

VHI (R_3) is also one of the predictors, which contributes least in the Multiple Regression equation shown in Table 4.7. It reveals that the body shapers have slight impact on the change of body volume and hence the variation of the average whole body attractiveness ratings (from 1 to 5.5).

Figure 4.4 shows the linear relationship between the actual average whole body attractiveness ratings ≤ 5.5 and the predicted body attractiveness ratings ≤ 5.5 in a regression model. This shows that the parameters in the regression equation have strong explanatory power to predict the attractiveness ratings.

Figure 4.4 Multiple Regression equation in Model 6 by comparison between predicted average whole body attractiveness ratings (from 1 to 5.5) and actual average whole body attractiveness ratings (from 1 to 5.5) from Multiple linear regression



4.3.2 Multiple Regression for attractiveness ratings > 5.5

The multiple regression equations for attractiveness ratings above 5.5 are shown in Table 4.8. The highest coefficient of determination of the multiple regression equation in Model 3 contributes R^2 of 0.969.

Table 4.8 Equations of AWAR, which are above 5.5 deriving by body parameters from MLR

Model	Equation from MLR	Correlation coefficient (R^2)
1	$3.985-0.678H_9$	0.837
2	$5.540-0.580H_9-0.246A_2$	0.94
3	$6.947-0.566H_9-0.329A_2-0.718B_{10}$	0.969

H_9 = Natural logarithm of Absolute deviation of Hip: Upper area/Lower area

A_2 = Breast contour area asymmetry

B_{10} = Breast: Upper area/Lower area

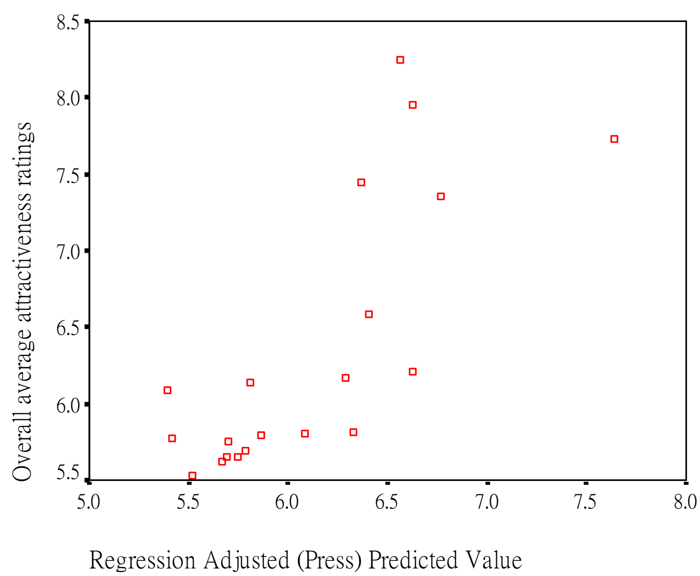
According to the Multiple Regression equation of Model 3, the whole body attractiveness is calculated by subtracting a constant value of 6.947 by each parameter term. That means the smaller the natural logarithm of absolute deviation from optimal of Hip: Upper area/Lower area (H_9), the greater the whole body attractiveness rating and the ratings are closer to a rating of 6.947. Moreover, as the images with smaller value of breast contour area asymmetry between right breast and left breast, the corresponding attractiveness ratings are higher. The smaller proportion of the breast upper area over breast lower area, in other word, smaller upper breast area over lower breast area makes the attractiveness ratings close to 6.947, i.e. the images get higher attractiveness ratings amongst this group of subject samples. It seems that judges gave an instant impression on each subjects' images, these impression determined certain whole attractiveness ratings of that images. Then judges tend to deduct ratings on those images under precise vision due to deviation from optimal H_9, the exact value of A_2 and B_{10} including in Model 3.

The results shown in Table 4.8 reveal that H_9 is very critical to determine the average whole body attractiveness ratings above 5.5. The best ratio of Hip: Upper area/Lower area (H_{ca1}/H_{ca2}) to achieve the highest attractiveness rating is 1.86. It indicates that the upper part hip contour area should be 1.86 times of the lower part of hip contour area in side profile. The best ratio of Breast:

Upper area/Lower area (B_{ca1}/B_{ca2}) is 1.5, which indicates the optimal upper breast contour area should be 1.5 times of the lower breast contour area. Besides, Breast contour area asymmetry (B_{caa}) is also a significant parameter to differentiate attractiveness of body images, which has the attractiveness rating over 5.5. The more symmetrical the breast contours are, the higher the attractiveness ratings that the images are obtained.

Figure 4.5 presents the relationship between the actual body attractiveness ratings above 5.5 and the predicted one based on regression Model. As the number of images being rated more than 5.5 attractiveness ratings are fewer, the trend of data plot is not clearly shown. However, the parameters contributed to a linear relationship in the regression Model 3 which has explanatory power to predict the attractiveness ratings.

Figure 4.5 Comparison between predictive average whole body attractiveness ratings (from 5.6 to 9) and actual average whole body attractiveness ratings (from 5.6 to 9) from Multiple Linear Regression.



4.4 Relative Importance of six body contour segments

There are only several particular attributes of body contours that are critical parameters to explain the whole body attractiveness. Perhaps judges only focus on some particular body contour segments instead of the whole silhouette of the body. The questions are which contour segment beauty is more important on body attractiveness judgment and which contours can be ignored. Therefore, the judges were asked to give ratings (from 1 is the most important contour segment to 9 the least important contour segment) on six body contour segments that influence the average whole body attractiveness. Referring to Table 3.12, the average ratings on each contour segments obtaining from the judges are shown in Table 4.9.

Table 4.9 The average ratings from judges about significant influence of six body contour segments on whole body attractiveness

Body contours	Average ratings	Description
Contour 1	6.188	Left side body in front view
Contour 2	6.044	Right side body in front view
Contour 3	7.969	Breast side profile
Contour 4	5.438	Abdomen side profile
Contour 5	4.063	Back side profile
Contour 6	7.125	Hip side profile

Table 4.9 shows that contour 3 obtains the highest rating of 7.969 in average, having the greatest influence on the whole attractiveness ratings. Contour 6 has the second highest rating of 7.125 in average. It means that judges not only concern the side silhouette of the breast but also the hip. Similar ratings of 6.188 and 6.044 are given to contour 1 and contour 2 respectively for the

left front and the right front profiles. The average rating of contour 4 is 5.438 and that of Contour 5 is 4.063. Such low values mean that they are less significant contour segments to influence the whole body attractiveness ratings.

Apart from the ratings given to different body contours, judges were also required to rank these contours. For example, the contour, which is assessed with the highest attractiveness rating, was ranked to 1 whereas the contour which is assessed with the lowest attractiveness rating was ranked to 6, as shown in Table 4.10.

Table 4.10 The sequence of rankings based on the scores of rating

Ratings of body contour	Rankings
The most significant	1
The second significant	2
The third significant	3
The fourth significant	4
The fifth significant	5
The last significant	6

Based on the rankings given by each judge on the six body contours, the percentages of judges ranked these six body contours as the most to the least significant influence on whole body attractiveness are shown in Table 4.11.

Table 4.11 The percentages of judges ranked six contour segments into ranking 1 to 6

Body contour	**1**	**2**	**3**	**4**	**5**	**6**	Total
Percentage of ranking 1 - The most significant contour	10.34%	0.00%	**82.76%**	0.00%	0.00%	6.90%	100%
Percentage of ranking 2 - The second significant contour	20.69%	10.34%	3.45%	6.90%	3.45%	**55.17%**	100%
Percentage of ranking 3 - The third significant contour	**48.28%**	13.79%	13.79%	13.79%	0.00%	10.34%	100%
Percentage of ranking 4 - The fourth significant contour	17.24%	**58.62%**	0.00%	6.90%	0.00%	17.24%	100%
Percentage of ranking 5 - The fifth significant contour	3.45%	17.24%	0.00%	**65.52%**	3.45%	10.34%	100%
Percentage of ranking 6 - The last significant contour	0.00%	0.00%	0.00%	6.90%	**93.10%**	0.00%	100%
Total	100%	100%	100%	100%	100%	100%	

There are 82.76% of judges assessing contour 3, the breast side profile, as the most significant contour. 55.17% of judges assessing contour 6, hip side profile, as the second significant contour. 65.52% and 93.10% of judges ranked contour 4 (the tummy contour in side profile) and contour 5 (the back contour in side profile) respectively as two least significant contours, which influence the whole body attractiveness. Obviously, the breast profile and the hip side profile dominate the determination of perception on the whole body attractiveness.

4.5 Attractive ratings on bust and hip contours

To verify whether these two contours really dominate and explain majority of the body attractiveness ratings, the judges were invited to assess only the breast contour of side profile and the hip side profile on each subject's body images by giving ratings from 1 to 9. Then the ratings of these two contours were put as variables in the multiple regression analysis to explain the whole body attractiveness ratings. The regression results are shown in the Table 4.12.

Table 4.12 Regression analysis of whole body attractiveness ratings predicting by attractiveness ratings of contour 3 and contour 6

Regression Statistics	
Multiple R	0.9145
R Square	0.8363
Adjusted R Square	0.8331
Standard Error	0.3321
Observations	108

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	59.143	29.571	268.129	0.000
Residual	105	11.580	0.110		
Total	107	70.723			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.390	0.155	2.513	0.013	0.082	0.698
Contour 3	0.481	0.038	12.767	0.000	0.406	0.555
Contour 6	0.431	0.048	9.040	0.000	0.337	0.526

The multiple regression equation is given in Equation 4.1

$$AWAR = 0.39 + 0.481C_3 + 0.431C_6 \quad (4.1)$$

where AWAR represents the average whole body attractiveness ratings, C_3 represents the attractiveness ratings given to Contour 3 and C_6 represents the attractiveness ratings given to Contour 6.

Based on the test results, there is 83.63% of whole body attractiveness ratings can be explained by the variation in attractiveness ratings of contour 3 and contour 6. For a given constant attractiveness rating of Contour 6, one additional score of attractiveness rating obtaining from Contour 3 leads to an increase of 0.481 in whole body attractiveness rating. On the other hand, for a given constant attractiveness rating of Contour 3, one additional score of attractiveness rating to Contour 6 makes an increase of 0.431 in whole body attractiveness rating. It can be obviously seen that the AWAR is partially determined by Contour 3 (breast side profile) and partially affected by Contour 6 (hip side profile). Furthermore, Contour 3 is more influential (coefficient = 0.481) than Contour 6 (coefficient = 0.431). The minimum rating is 0.39 + 0.481 + 0.431 = 1.302 when both C3 and C6 are equal to 1 while the maximum rating is 0.39 + 0.481 × 9 + 0.431 × 9 = 8.598 when C3 and C6 are equal to 9.

As p value is 0.00, which is smaller than 0.05, this multiple regression equation can significantly interpret the relationship between whole body attractiveness ratings and attractiveness of Contour 3 and Contour 6. It also shows that the attractiveness of contour 3 (breast side profile) and Contour 6 (hip side profile) really have strong positive explanatory power to explain whole body attractiveness.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Anthropometric Study

In this study, 18 women subjects in a range of age from 20 to 26 years old and BMI from 18.5 to 24.9 kg/m^2) were selected from sixty-eight women volunteers. To ensure the accuracy of manual body measurements, a movable laser pointers rod was developed for marking the critical body points before taking measurements. Anthropometric measurements including the width, depth, height and circumference measured at full bust, underbust, waist and hip were then taken using Martin anthropometer. The Body Composition Analyzer was used to measure the bone mass (B_m), muscle mass (M_m), total body water (BO_{wat}), body fat (BO_f). Moreover, the body weight was recorded from a digital balance. All these data was useful for the computation of body parameters to be later investigated in the principal component analysis.

5.2 Body scanning

Before and after wearing body shapers, eighteen women subjects were scanned by a TecMath 3D laser scanner. The body profiles from side and front view were then visualized. A computer program has been developed to obtain the height, depth and width, cross sectional area and volume at specified body levels such as bust, waist, abdomen and hip. Another program was also developed to derive the body contour smoothness, symmetry and shape of the front and side body profiles.

We anticipated that the body contour traits of the subjects' scanned images could influence the visual perception of body attractiveness. The contour traits include 1) contour smoothness of the left and right contour in the front profile and the abdomen in side, back and hip contour in the side profile, 2) contour symmetry of two sides and breasts, 3) Contour shape of the hip and breast.

5.3 Body Attractiveness Evaluation

A total of 15 bra styles and 8 girdle styles that claimed to provide body-shaping functions were selected from four leading brands in the local market. To identify the correlation among body parameters (including body sizes, ratios, contour traits) with and without body shapers, 40 professional consultants were recruited to be judges in this experiment. They had at least two years working experience (mean = 5.3 years) in assessing women's body figures and providing advice to customers on choosing suitable intimate apparel. Using 9-point Likert scale assessed the side and front profiles of the scanned image of each subject with and without body shapers. The scale is ranging from 1 for the least attractive image to 9 for the most attractive image. Each subject had tried five different sets of body shapers for evaluating the improvement of body attractiveness.

5.4 Results from statistical analysis

5.4.1 Effects of Body shaper on body attractiveness

By the results from paired t-Test, the mean average attractiveness ratings (ARs) given to the 90 scanned images from the 18 subjects wearing 5 sets of body shapers is 6.05, while that of naked bodies is 4.79. It reveals that there is a significant increase of 1.26 in average body attractiveness after wearing body shapers. It confirmed that body shapers have significant effect on improvement of body attractiveness.

5.4.2 Body ratios that explain body attractiveness

The evaluation of body ratios, such as Wacoal Canon Ratio, BMI, WHR, VHI, on prediction of nude body attractiveness, confirmed that these ratios have better explanatory power on body attractiveness in assessing only nude body images, but weak in assessing clothed images. Among these ratios, BMI and VHI have better performance in assessing both the average nude body images and average whole body images (including nude and clothed images). The correlation coefficient of BMI with average nude body attractiveness ratings is -0.736 and the correlation coefficient of VHI with average nude body attractiveness ratings is -0.738. However, the correlation between the average attractiveness ratings of nude body and the WHR, Wacoal Golden Canon Ratio ($B:W:H_f$) or Wacoal Golden Canon Ratio ($B:W:H_s$) is much weaker. Their correlation coefficients are -0.363, 0.504 and 0.454 respectively.

For those images with body shapers, the correlation coefficient of BMI with average whole body attractiveness ratings is decreased to -0.416 and the correlation coefficient of VHI with average whole attractiveness ratings becomes -0.521. The correlation coefficient of WHR, Wacoal Golden Canon Ratio ($B:W:H_f$) and Wacoal Golden Canon Ratio ($B:W:H_s$) with average whole body attractiveness ratings are all further decreased to -0.278, 0.390 and 0.387 respectively.

It confirmed that although VHI and BMI are better ratios to explain body attractiveness ratings when compared with WHR, Wacoal Golden Canon Ratio ($B:W:H_f$) and Wacoal Golden Canon Ratio ($B:W:H_s$). They are not strong enough to interpret the body attractiveness ratings with nude and clothed images. Therefore, a multiple regression analysis was used to determine the correlations among 108 body attractiveness with and without body shapers, the 68 body parameters and their body ratios, proportions and body contour traits (Contour smoothness, contour symmetry, contour shape).

5.4.3 Different judgment for attractiveness ratings below and above 5.5

From the body attractiveness ratings and body parameters of 108 body images, the high coefficient of determination (R^2 = 0.932) in multiple regression equation revealed that five body parameters, which are related to breast and hip contour shape, have great contribution in the prediction of average whole body attractiveness. However, the data trend showed that body parameters H_{10} and B_{20} do not contribute an increase in attractiveness rating for the images when it is greater than 5.5. Therefore, the attractiveness ratings given to the 108 images were divided into two groups and multiple regression tests were performed with those 68 parameters for the two groups, one group with attractiveness ratings between 1 to 5.5 and another group is above 5.5.

For the data set of attractiveness ratings from 1 to 5.5, the highest coefficient of determination (R^2 = 0.978) in multiple regression equation was contributed by six parameters:

B_5 = Absolute deviation from optimal Breast: upper angle

H_{10} = Absolute deviation from optimal Hip: lower area/Total hip height

H_{23} = Absolute deviation from optimal Hip: Outer angle from waist to hip side

H_{19} = Absolute deviation from optimal Hip: Radius of 45^o from hip centre to contour line

B_{20} = Absolute deviation from optimal Breast: Radius of 15^o from bust centre to contour line

R_3 = Absolute deviation from optimal Body volume/Height^2 (VHI)

B_5 and H_{10} are the two main predictors that explaining 95.4% of average whole body attractiveness ratings. That means judges mainly focused on the proportion between height and length of upper breast, protruding level of lower hip under certain proportion of high height in side profile.

5.4.4 Optimal attractiveness

It was also found from the multiple regression equation that the whole attractiveness is calculated by subtracting the weighted body parameters from a constant optimal rating of 5.841. It seems that judges first gave an instant impression on each subject's images in assessment process and this impression determined certain whole attractiveness ratings of that image. Then judges tended to deduct ratings on those images, which deviated from the optimum values of the 6 parameters.

The best breast upper angle (B_5) was 21.72° while the best hip: lower area/Total hip height (H_{10}) is 47.01. The best protruding angle of upper hip from waist to hip in the side profile is 68^o. The deviation from the optimal ratio of Hip: Radius of 45^o from hip centre to contour line (H_{19}) is 1.07 and the deviation from the optimal ratio of Breast: Radius of 15^o from bust centre to contour line (B_{20}) is 0.99. It reflects that the rounded lower breast is preferred.

For the data with attractiveness ratings greater than 5.5, the highest coefficient of determination, R^2, of 0.969 in multiple regression equation determination was contributed by three parameters:

H_9 = Log of Absolute deviation of Hip: Upper area/Lower area

A_2 = Breast contour area asymmetry

B_{10} = Breast: Upper area/Lower area

Similar to the results obtained in previous case of attractiveness rating between 1 to 5.5, the whole body attractiveness is calculated by subtracting the weighted body parameters from a constant optimal rating of 6.947. Judges tended to focus on the delicate proportion between upper contour area and lower contour area of hip and breast, and also emphasis on the symmetry of breast in side profiles. The best ratio of Hip: Upper area/Lower area (H_{ca1}/H_{ca2}) to achieve the highest attractiveness rating is 1.86 while the best ratio of Breast: Upper area/Lower area (B_{ca1}/B_{ca2}) is 1.5. Besides, breast contour area asymmetry (B_{caa}) is also a significant parameter to differentiate attractiveness of body images that have the attractiveness rating over 5.5.

It can be concluded that judges focused on two different groups of body parameters for body images rated below ‘5.5’ and that above ‘5.5’. Judges assessed body images focusing on the proportion of height and length level on breast and lower hip. If the body images are good enough in these certain proportions, the images can be rated above 5.5. Whether the images can be rated toward 9 (the highest attractiveness ratings) depend on the proportion between upper contour area and lower contour area of hip and breast, and also the symmetry of breast in side profile.

5.4.5 Significance of different body contours

The result of statistical analysis between contour segments on the significant influence of whole body attractiveness ratings showed that the breast contour of side profile (contour 3) was given to the highest rating of 7.969 in average. It means that attractiveness of contour 3 has the greatest influence on the whole attractiveness ratings. Meanwhile, the hip contour of side profile (contour 6) was given to the second highest rating of 7.125 in average. It means that judges not only concern the side silhouette of the breast but also the hip. Moreover, there is 82.76% of judges assessed contour 3 to be the most significant contour and there is more than half (55.17%) of judges assessed contour 6 to be the second significant contour. It confirmed that the breast contour of side profile and the hip contour of side profile dominate the determination of perception on the whole body attractiveness.

To determine whether these two contours can explain most of the body attractiveness ratings, the multiple regression equation contributed by attractiveness ratings of breast contour of side profile and the hip contour of side profile on each of subjects' body images was used to explain the whole body attractiveness ratings. Contour 3 and contour 6 are significant variables to explain whole body attractiveness ratings where the coefficient of determination is 0.8363. The breast and hip contour of the side profiles dominate the whole perception of whole body attractiveness. In other words, judges can mainly determine the whole body attractiveness.

In this thesis, some contour parameters have demonstrated the ability to effectively explain the whole body attractiveness ratings with or without wearing body shapers by using multiple regression equations. This explanatory power is particularly important to determine the body attractiveness ratings by substitute their measurement data of some contour parameters into multiple regression equation so as to retrieve their body attractiveness ratings with or without wearing body shapers. Moreover, the test result has also demonstrated the breast and hip contour of side profile are particular significant to determine the whole body attractiveness. This provides a general guideline for producers of intimate apparel that their intimate apparel should focus on these two contours to satisfy what their women's want.

In the modern economy, women are getting rich and more active. They are looking for an upgrade of social esteem and self-actualization, a pride on body attractiveness definitely enhances the self-confidence. However, those body shapers claimed to beautify the wearer's body had no standard of the desired body shape. Designers usually make the garments with certain tension, aiming to reduce the wearer's waist and abdomen size, but the shaping effect is not evaluated quantitatively.

This study is helpful for garment designer to recognize the ideal and useful body parameters for garment construction to improve body attractiveness. It also provides guidance for individual woman to understand how the body shaper can enhance her attractiveness.

5.5 Limitations

Some limitations have been found in this study:

1) Judges are 40 female consultants of intimate apparel. This project only shows the professional views of body images, the attractiveness ratings may deviate from the public views.
2) As live subjects were used in this project, their slight movement during scanning process may affect the accuracy of the 3D data that the measurements were based on.
3) Although 18 subjects with normal BMI were selected from 80 women, the subject size was small to generalize the ideal body shape by using regression models.
4) There is no standard to identify the features of body shapers; it is possible to miss out Garment samples that provide different body shaping function.

5.6 Recommendations for Future Research

For further study, judges in different sex, age groups, native and academic background should be recruited. This can improve the validity of the multiple regression statistical results to be generally applied.

The validity of the testing results highly depends on the accuracy of body measurement data obtained from body scanning and anthropometric measurements based on the vivid levels of the body image profiles. The slight movement of human body may affect the measurement data and blur the body profiles. In my opinion, a number of soft mannequins can be used in further study so that the static measurement data can be obtained accurately and efficiently. It will be better to use photogrammetry methods to image capturing instead of laser scanner. So Clear body profiles can be obtained without missing holes and for judgment can be made more accuracy.

In order to reconfirm the ability of the regression models for determining the body attractiveness, larger subject samples and repeated tests by random selection should be carried out. In this case, the subjects probably need to be assessed in different controlled groups.

For further research, the investigation about comparison between the best selling items of body shapers and other similar items will be interesting. Some common specifications possessed by the best selling body shapers can be identified. These specifications provide certain hints on what characteristics of body shapers are favorable to women. This information identify the guideline and standard of what body shapers that the public are looking for and determine what shaping effect that are desired for with wearing body shapers.

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