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Classification of male lower torso for underwear design

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Abstract. By means of scanning technology we have got new information about the morphology of male bodies and have redistricted the classification of men's underwear by adopting one to consumer demands. To build the new classification in accordance with male body characteristic factors of lower torso, we make the method of underwear designing which allow to get the accurate and convenience for consumers products.

1. Introduction

Contemporary design and labeling of men's underwear based only on the main body sizes (such as waist and hip girth, height) and age (for children, adults, elderly). Consumer demands need more information about specific features and construction of underwear to be sure about wearing comfort and suit especially in waist and crotch areas [1]. On the other side, the contemporary fashion is considering and combining two styles of trousers and underwear to get fashionable and good-looking image of men [2]. Closely fitting trousers, especially skinny, should be equipped by underwear with shaping or compressive functions [3-5]. So, the anthropometric and methodological data bases should be renewed to design more comfortable and with many functions contemporary underwear.

2. Experiment steps

2.1. Schedule of body dimensions for classification

We have measured 60 Chinese males (19...25 year old) by Vitus Smart XXL 3D body scanner.

Table 1. Male body sizes, cm

Parameter	Body sizes					
	Height	Waist girth	Hip girth	Body rise (waist to crotch level)	Navel to crotch level	Hip girth - waist girth
Average	177.2 ± 10.0	75.2 ± 5.7	94.1 ± 4.8	32.2 ± 2.0	26.1 ± 0.9	18.9 ± 4.0
Range	161.2...206.7	64.2...92.5	93.6...114.1	28.3...36.0	20...31.7	8.4...29.4

Figure 1a shows the differences existing between 13 joining cross-sections taken from scanned bodies with the same waist and hip girth. So, to present the morphological features of real bodies' new combination of body dimensions should be established.



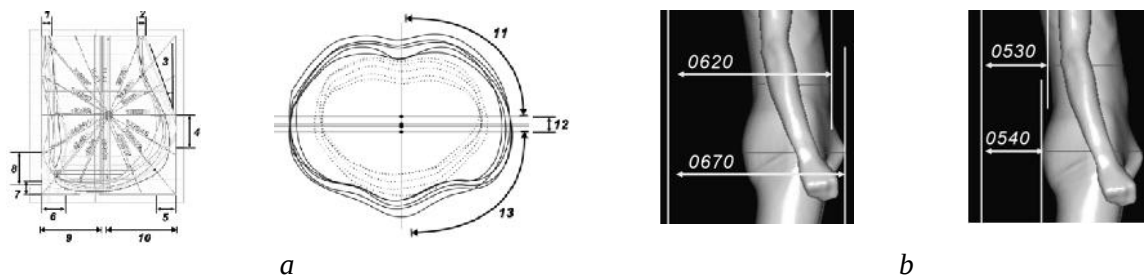


Figure 1. Vertical and horizontal cross-sections (a) and new body dimensions to express the shape of genitals and hip bulge (b)

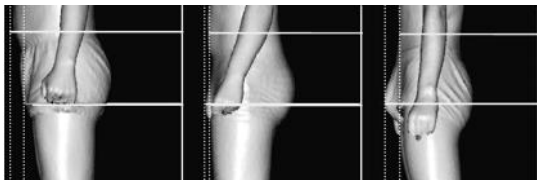
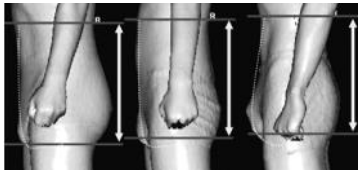
To decrease the number of indexes, we developed new approach of lower torso classification for underwear design. Firstly, based on the method of body type classification by the difference between bust and waist girth according with the Chinese *GB/T 1335.1-2008 Standard sizing systems for men garments* [6-8], we used the same principle to classify. We calculated the difference between hip girth (HG 7520) and waist girth (WG 6510) and then divided all male lower torsos into 3 types — **A, B, C**. The average value of HG - WG is 18.9 cm, standard deviation is 4 cm. So, we established 3 intervals that based on types **A, B, C** as now, but we added the sub-types such as I, II, III, IV, V, VI.

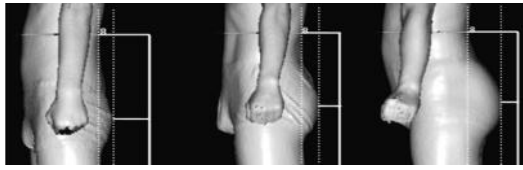
Secondly, we proposed some new dimensions (figure 1b) to express the morphology of front (0620 is distance between more prominent point of belly and vertical, 0670 is distance between more prominent point of genitals and vertical) and buttock (0530 is distance between waist back point and vertical, 0540 is distance between buttock points and vertical).

2.2. Way of new classification

We used the next body dimensions as the base of new classification: For the volume of front and back, we selected the horizontal distance in figure 1b to calculate. D_{GR} can describe the position between genitals and belly bulge. By this way we can determine the value of genitals bulge, adjust the waistband and bulge value into construction of front insert in pattern block. V_F can describe the volume of genitals (length of front insert), we take the straight-line distance of body rise as reference to calculate index V_F . D_{BH} can describe the position between the waist concave and the hip bulge, we can determine the value of hip. V_B can describe the volume of hip (length of back).

Table 2. Explanations of new classification index

Male lower torso profile	Index
	D_{GR} is difference 0670 - 0620 as the value of waist front to the peak point of genitals bulge. During -0.9 ... 2.4 cm, the average value is 0.58 cm, standard deviation is 0.67 cm. We divided the range of D_{GR} into 3 intervals: (1) < -0.1 cm, (2) - 0.1 ... 1.3 cm, (3) > 1.3 cm. In investigated group 10 males have had negative values, 50 males have positive values.
	V_F is difference CL_F - BR, during 6.5 ... 12.4 cm, average is 9.4 cm, standard deviation is 1.1 cm, so we divided into 3 intervals, there are (1) < 8.3 cm, (2) 8.3 ... 10.5 cm, (3) > 10.5 cm.



D_{BH} is difference 0530 - 0540 as the value of waist back arc to the peak point of hip back. During 1.1 ... 8.8 cm, the average value is 3.83 cm, standard deviation is 1.55 cm, We divided the value into 3 intervals based on the range, there are (1) < 2.1 cm, (2) 2.1 ... 5.5 cm, (3) > 5.5 cm.

V_B is difference $CL_B - BR$, during 3.6 ... 11.3 cm, average is 7.1 cm, standard deviation is 1.5 cm. We divided the range into 3 intervals, there are (1) < 6.2 cm, (2) 6.2 ... 8.8 cm, (3) > 8.8 cm.

We divided all bodies into 3 levels (table 3). The range of CL_F is 35.8 ... 46.9 cm, the average value is 41.6 cm, and the standard deviation is 2.5 cm. The range of CL_B is 34.1 ... 44.2 cm, the average value is 39.3 cm, and the standard deviation is 2.2 cm.

Table 3. New classification based on the new body sizes

Levels of classification	Torso features	Dimensions	Calculations	Index
1st	Total sizes	HG, WG	$\Delta = HG - WG$	Type A, B, C
2nd	Genitals bulge	D_{GR} , CL_F , BR	$D_{GR} = 0670 - 0620$; $V_F = CL_F - BR$	Group I,II, III
3rd	Buttock bulge	D_{BH} , CL_B , BR	$D_{BH} = 0530 - 0540$; $V_B = CL_B - BR$	Group IV,V,VI

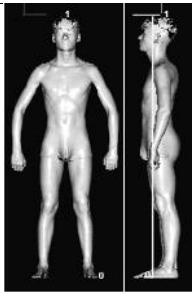
Using the dimensions from Tables 1-3, we divided all 60 bodies in accordance with new approach. Table 5 shows the examples of body's identification by means of new classification.

Table 4. Range of new classification of male torsos, cm

Types and ranges				Std. Dev.
First level	A (Small)	B (Medium)	C (Large)	
HG, cm	$HG < 89$	$89 \leq HG \leq 97$	$HG > 97$	-
Δ , cm	< 15	$15 \leq (HG - WG) \leq 23$	> 23	± 4
Second level	I	II	III	-
D_{GR} , cm	0	$0 \leq D_{GR} \leq 1.3$	> 1.3	± 0.6
V_F , cm	< 8.3	$8.3 \leq V_F \leq 10.5$	> 10.5	± 1.1
Third level	IV	V	VI	-
D_{BH} , cm	< 2.1	$2.1 \leq D_{BH} \leq 5.5$	> 5.5	± 1.5
V_B , cm	< 6.2	$6.2 \leq V_B \leq 8.8$	> 8.8	± 1.5
Total Proportions,	13 ... 16	69 ... 77	10 ... 15	-

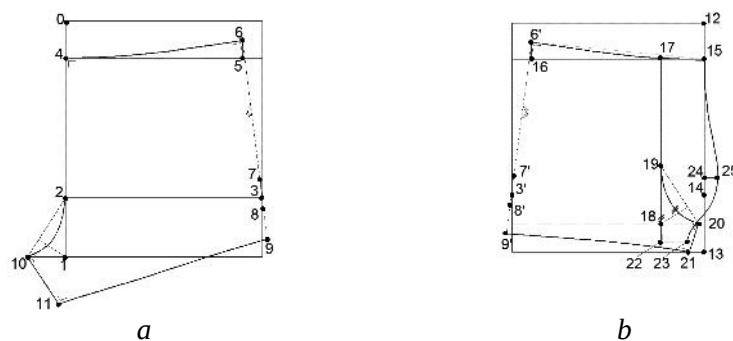
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Table 5. Examples of male torso identification

Type A-I-IV	Type B-II-V	Type B-III-V
		
HG: 88.7 Δ : 10.7 D_{GR} : -0.1 V_F : 6.5 D_{BH} : 2.0 V_B : 5.9	HG: 92.1 Δ : 19.4 D_{GR} : 1.1 V_F : 10.0 D_{BH} : 2.3 V_B : 7.4	HG :95.1 Δ : 22.2 D_{GR} : 1.7 V_F : 10.6 D_{BH} : 5.6 V_B : 6.4

2.3. Pattern block designing

We have developed the new method of the pattern block designing of underwear and have selected the reasonable ease allowance of knitted materials according to the new classification [9]. Figure 2 shows the example of underwear pattern block that was build by the dimensions /4-6/, /6'-15/ (according with *First level* from Table 4), length /24-25/ (genitals bulge), /17-15/ and curve /15-23/ (according with *Second level*) and the length (back crotch width) /10-1/, curve /4-10/ (according with *Third level*).

**Figure.2** Basic pattern block of underwear: *a* - back, *b* - front [9]

3. Conclusion

Based on these main indexes, we have classified the male lower torsos into special groups with its morphology characteristics. Also we have prepared the recommendations how to design the underwear pattern block for different types of bodies, to choose the structure of underwear with more reasonable and satisfy characteristics in accordance with the male body morphology. Furthermore, the new classification could help consumer to choose the underwear that can be labeled by new way.

Next step we will include 3D simulation try-on.

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