For a good fitted skirt, the waist-to-hip distance should be measured

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Abstract
The aim of this study was to compare waist-to-hip distances from contemporary construction systems with the measured waist-to-hip distance of the Slovenian young female population to establish which waist-to-hip distance present in different contemporary construction systems best fits the body dimensions of that specific market target group. A total of 156 female students (aged from 19 to 27 years) from the University of Ljubljana (Slovenia) volunteered in the study. The results showed that the measured waist-to-hip distance differed significantly from those obtained from the tables of the contemporary construction systems or calculated as a secondary measure according to these systems. The differences between measured waist-to-hip distance and other analysed waist-to-hip distances increased as a size group increased and, at the same time, the range of measured waist-to-hip distances inside each size group were substantial. In conclusion, the values for waist-to-hip distances as proposed by different contemporary construction systems differ significantly from the measured one in the young Slovene female population. Including the waist-to-hip distance as a directly measured parameter in the future anthropometric surveys is recommended.

KEYWORDS: pattern construction, anthropometric measurements, waist-to-hip distance, skirt, basic block pattern

Introduction
The skirt represents an indispensable piece of apparel in every woman's wardrobe. Because the expectations of contemporary customers are increasing steadily and are accompanied by an abundant offer of skirts by different producers and retailers, the proper size and fit of the clothes is important and influence the buying decision of the customers (Alexander, Connell & Presley 2005). The fit of the clothes is closely linked to the body dimensions incorporated in the basic pattern blocks of the clothes, while every production of garments requires the development of corresponding patterns. Measurement tables and basic block patterns in the industry are already established and fixed, but they are not necessarily the best reflection of the body dimensions of their target market groups (Podbevšek 2004; Schofield & LaBat 2005; Ashdown & Dunne 2006). Since sizes and proportions

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of human bodies are constantly changing due to various factors (Katzmarzyk & Leonard 1998; Starc & Strel 2011) there is a constant need in updating the standards of fashion industry by the help of physical anthropology with its anthropometric measurement techniques (Beazley 1997; Bolstad, Benum & Rokne 2001; Ujević et al. 2006; Hsu 2009) and recently developed 3D body scanning techniques (Istook & Hwang 2001; Simmons & Istook 2003). This has been problematised already in 1947, when Mansfield Lonie of the US National Bureau of Standards appealed to physical anthropologists that '… the mass production of ready-to-wear apparel might satisfy the needs of … people better, if physical anthropologists could direct some of their thoughts and energies to the needs of the apparel industry' (Lonie 1947: 353).

The waist-to-hip (WtH) distance, as well as hip depth, is one of the necessary measures needed for developing the basic skirt pattern block and plays an important role in creating the proper fit of the skirt on the level of the largest hip girth. If it is shorter from the real one, the skirt will be too loose, if it is longer, the skirt will be too tight above the widest hip level. Contemporary construction systems often overlook its influence on the fit of the skirt to the body. In practice, their waist-to-hip distance is usually defined as a standard measure approximately 20 cm long (Stiegler & Krolopp 1996), or as a secondary measure that can be calculated with equation from one of the primary measures. Within the Hungarian so-called decimal system (Julean & Halász, 2001) it is calculated as a tenth part of the body height (e.g. 1/10 of 168 cm of body height will result in 16.8 cm waist-to-hip distance), while in the German Müller system the equation as one tenth of the bust girth plus 10.5 or 11.0 or cm is used (Stiegler 1997; Stiegler & Krolopp 1994; Stiegler & Krolopp 1996). In addition, most of the contemporary construction systems include it in their measurement tables. The values in those tables are slightly different from one system to another and increase with the change of the hip girth (Aldrich 2008; Stiegler & Krolopp 1996; Mors De Castro 2010; Carvelli & Ruggeri 1999; Joseph-Armstrong 2006).

Differences of WtH distances from different construction systems set with measurement tables or with equations raise a question: which distance fits best to the natural shapes of different target groups of female bodies? One way to find the answer is to compare these distances with those from the real subjects. There is no universal agreement on how to measure WtH distance, while construction systems offer different measurement methodologies (Aldrich 2008; Stiegler & Krolopp 1996; Mors De Castro 2010; Hollman 2004, ISO 8559:1989). It seems that the most consistent way to select the proper methodology is to follow the nature of basic skirt pattern block development. In most of the pattern construction systems, the WtH distance is applied in the basic pattern block as a vertical distance between the natural waist and hip levels in the middle front of the body (Aldrich 2008; Stiegler & Krolopp 1996; Joseph-Armstrong 2006). In the same way, the methodology of measurement WtH distance in our anthropometric survey was performed.

The aim of this study was to compare WtH distances from contemporary construction systems with the measured WtH distances of the young Slovenian female population to establish which WtH distance presented in different contemporary construction systems fit best to the body dimension of that specific market target group.

Method
Sample
The anthropometric surveys were carried out on 156 female students (aged from 19 to 27 years) from the University of Ljubljana (Slovenia) who volunteered in the study. Since the measurement tables of contemporary construction systems are composed for specific body heights, the students were selected to be of similar body height 168 cm (from 164 cm to 172 cm) as a size group suggested by SIST EN 13402-3 standard (SIST EN 13402-3 2005). All participants were well informed about the procedures of the experiment. None of them had given birth.

WtH distances from the measurement tables
The WtH distances were obtained from the measurement tables of the following contemporary construction systems: Müller's system (Stiegler & Krolopp 1996), Aldrich's system (Aldrich 2008) and Mors de Castro's system (MdC) (Mors De Castro 2010). In Müller's and Mors de Castro's systems, the WtH distances were calculated by subtraction of the back length from hip depth values from their measurement tables. Müller's system provides two measurement tables with different values; therefore, two set of values (Müller1 and Müller2) were composed for the purpose of this study. The values obtained from the tables were valid for the female population between 164 and 172 cm body height (168 cm) and for selected size groups based on hip girth (88 cm to 104 cm).

WtH distances calculated with the equations
The first calculated WtH distance was based on Müller's system equation (Equation 1) (Stiegler & Krolopp 1996; Stiegler & Krolopp 1994; Stiegler 1997):

$$WtH\_B = BG / 10 + 11$$

where BG stands for bust girth. This equation result from the equation of Müller's system for hip depth (measured from the (7th cervical) bone to the hip line) which is back length plus armscye depth. Armscye depth is further offered as one tenth of bust girth plus 11 cm in one variety of the equation and plus 10.5 cm in another. From this connection, we can conclude that the WtH distance has the same equation as the armscye depth, which is BG / 10 + 11.

The second calculated WtH distance was calculated according to Equation 2, based on a decimal base pattern design for women's clothes (Julean 2001):

$$WtH\_10 = BH / 10$$

where BH stands for body height.

The bust girths and body heights of the subjects were measured according to the procedures described in the anthropometric survey.

Anthropometric survey

During the measurement, the participants were standing on level ground in their natural posture with the feet together and with the centre of gravity distributed equally on both legs. Their heads were aligned with Frankfurt's line. During the measurement, they breathed regularly with their abdomens relaxed, with arms freely hanging down along the torso or slightly lifted up, but in such a way that their posture or body dimensions under consideration did not change. Participants were dressed in their underwear and barefoot. The survey was performed in the morning by the same person and an assistant who recorded the data. The values were always repeated before they were put into the anthropometric form and were round up to the higher value with 0.5 cm accuracy. First, the anthropometric planes were selected and marked with 3mm wide elastic band, which did not compress the soft tissue and thereby affect the values of measurement. These planes included the natural waist level (upper band) between the top of the hip bones and the lower ribs where the girth is the smallest, and the hip level around the buttocks at the level of maximum circumference (lower band) (Figure 1 left) as suggested in ISO 8559 (ISO 8559 1989) and ISO 3635 (ISO 3635 1981). The bands were adjusted around the body in a way that the ellipsoid levels of the girths were perpendicular to the longitudinal axis of the body.

Hip girth was measured by using a dimensionally stable tape-measure that was placed below and along the thin elastic band on the hip level. It was compressed around the body in such a way that it touched the skin across the complete distance and at the same time it did not deform the soft tissue beneath (Figure 1, left).

The measured waist-to-hip distance (WtH_m) was taken as the vertical distance between the upper edges of the strings in the natural waist and hip level in the frontal centre in the middle of the body (Figure 1, middle).

The bust girth was measured with dimensionally stable tape-measure as the maximum horizontal girth during normal breathing with the subject standing in her natural posture and tape-measure passed across the nipples but adjusted around the body

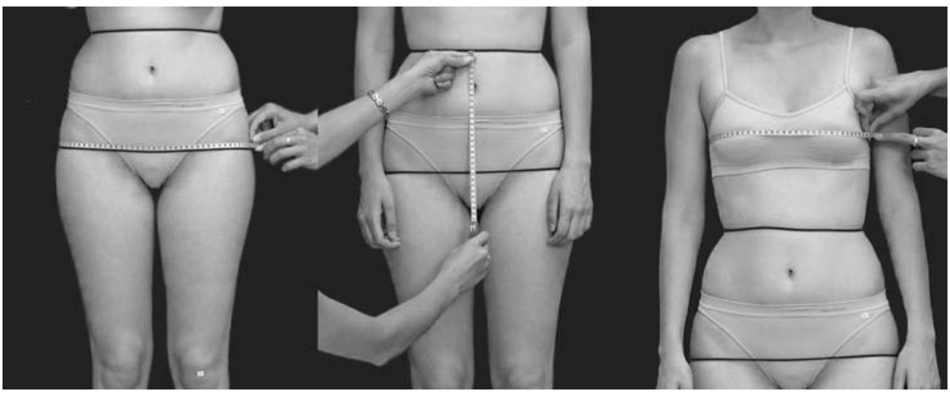

Figure 1: Measurement of the hip girth (left), waist to hip distance (middle) and bust girth (right)

in a way that the ellipsoid level of the bust girth was perpendicular to the longitudinal axis of the body (Figure 1, right).

The measurements of body height (BH) were performed with anthropometer as the vertical distance between the crown of the head and the ground, with the subject standing in their natural posture with the feet together.

Statistical analysis

The participants with an average body height of 168 cm (from 164 cm to 172 cm (SIST EN 13402-3 2005) were arranged into size groups according to their hip girth in the range of 4 cm as suggested in SIST EN 13402-3. Five size groups were formed with hip girts 88 cm (from 86 to 90 cm), 92 cm (from 90.5 to 94 cm), 96 cm (from 94.5 to 98 cm), 100 cm (from 98.5 cm to 102 cm) and 104 cm (from 102.5 cm to 106 cm).

For each group, basic statistical parameters of analysed variables were calculated. Statistical significances of the differences among the groups were first tested with ANOVA and then with post-hoc T-tests for single pairs of groups (Bonferroni correction). Statistical significances of differences among different waist-to-hip distances (measured and calculated) inside the single size group were tested first with ANOVA and then with post-hoc T-tests for single pairs of variables (Bonferroni correction). Pearson correlation coefficients were calculated between measured and calculated WtHs and the obtained anthropometrical measurements. The results were statistically processed with SPSS (version 22, IBM SPSS, New York, USA). The alpha error was set to 5% (two-tailed).

Results

The waist-to-hip distances obtained from different tables of the included contemporary construction systems are presented in Table 1. Among the systems, Müller1 consistently gives the lowest values while Aldrich provides the greatest values for all size groups. The greatest difference among systems is observed in the smallest size group; afterwards, the differences decrease. However, the differences among systems are small (less than 1.3 cm). The smallest waist-to-hip distance is 19 cm in Müller1 for women with hip girths of 88 cm, and the largest is 21.2 cm in Aldrich for the women of hip girths of 104 cm. Inside the single construction systems, the differences among size groups are rather small (0.8–1.6 cm).

Table 1: Waist-to-hip values obtained from different measurement tables of women with different hip girths.

Groups	88 cm	92 cm	96 cm	100 cm	104 cm	Max-min
Müller1	19.0	19.4	19.8	20.2	20.6	1.6
Müller2	20.0	20.4	20.6	20.8	21.0	1.0
Aldrich	20.3	20.6	20.9	21.2	21.2	0.9
MdC	-	20.2	20.6	20.8	21.0	0.8
Max-min	1.3	1.2	1.1	1.0	0.6	

Legend: Values in the table are in cm. Max-min – difference between maximal and minimal distance.

Participants from different size groups did not differ statistically significantly (p=0.798) regarding their age (Table 2). However, their body height was statistically significantly different (p=0.038) among the size groups, which consequently led to statistically significant differences ($p < 0.038$) in calculated WtH distances from the body height (WtH_10) among the groups. Mean differences among size groups were also statistically significant in WtH_B (WtH distances calculated from the bust girth). The mean WtH_B distances were in a range from 19.3 cm to 20.5 cm, and in a range from 16.7 cm to 16.9 cm for WtH_1/10 (WtH distances calculated from the body height). Although the differences among groups were statistically significant, they were small in the absolute values up to 1.2 cm). Between the WtH_10 and WtH_B the differences in mean distances were substantial (from 2.6 cm to 3.6 cm) and significant ($p < 0.001$).

Table 2: Age, body height and calculated values for WtH distance as measured on the study's participants with 168 cm of body height (from 164 cm to 172 cm)

		Age (years)		**BH (cm)**		**WtH_B (cm)**		**WtH_10 (cm)**	
Groups	N	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
88	17	21.5	2.15	167.0	1.89	19.3	.29	16.7	.19
92	38	21.5	1.23	167.6	2.34	19.4	.39	16.8	.23
96	52	21.3	2.14	168.4	2.37	19.9	.46	16.8	.24
100	31	20.0	1.49	168.8	2.54	20.0	.42	16.9	.25
104	18	21.9	1.78	168.7	1.86	20.5	.59	16.9	.19
Sig.	P	0.798		0.038		0.000		0.038	

Legend: BH – Body height, WtH_B – WtH distances calculated from bust girth, WtH_10 – WtH distances calculated from body height, Sig. – statistical significance of differences among groups' means.

Results of the WtH distance as measured in this study are presented in the Table 3. Mean values increased from the smallest size group (22.35 cm) to the largest size group (25.89 cm). The differences among size groups are statically significant ($p < 0.001$). Analysis of the difference between pairs of size groups (Table 4) showed the three largest size groups did not differ statistically significant. The differences between size groups 92 and 96 were non-significant noting that similar trend was also observed in the smaller size groups. The greatest difference in mean distances between size groups was 3.54 cm.

Table 3: Waist-to- hip distances as measured on the study's participants

Group	**N**	**Mean**	**SD**	**Std. Error**	**95% Confidence Interval for Mean**		**Min**	**Max**
					Lower Bound	Upper Bound		
88	17	22.35	2.23	.61	21.07	23.64	19.0	28.0
92	38	24.07	2.46	.44	23.17	24.97	19.0	30.0
96	52	24.07	2.38	.32	23.43	24.71	16.5	30.0
100	31	25.55	2.75	.45	24.64	26.46	20.0	29.5
104	18	25.89	1.89	.44	24.95	26.81	22.0	30.0
Sig.	P	0.000						

Legend: Values in the table are in cm, Sig. – statistical significance of differences among groups' means.

Table 4: Values of statistical significance of mean differences for measured waist-to-hip distances between size groups (means are presented in Table 3)

Groups	88	92	96	100
92	0.169			
96	0.123	1.000		
100	0.000	0.127	0.083	
104	0.000	0.096	0.070	1.000

The difference between Table 1 values, calculated mean WtHs and measured mean WtH for single size groups are presented in Table 5. The most striking observation was a substantial difference regarding the construction systems and the measured WtH in all size groups. In most cases, the values differ by 3 cm or more. The largest differences were between WtH_10 and WtH_m (between 5.52 and 8.93 for different size groups). WtH_B agreed well with values in Table 1.

Table 5: Differences between WtH distance from the construction systems (based on Table 1 and calculated WtHs), and mean measured WtH

	88	92	96	100	104
Müller1	3.35	4.67	4.27	5.35	5.29
Müller2	2.35	3.67	3.47	4.75	4.89
Aldrich	2.05	3.47	3.17	4.35	4.69
MdC	3.53	4.58	5.12	5.27	
WtH_B	1.4	3.09	3.19	4.4	4.69
WtH_10	5.52	7.22	7.35	8.55	8.93

Legend: MdC – Morse de Castro, WtH_B – WtH distances calculated from bust girth, WtH_10 – WtH distances calculated from body height.

A comparison of mean distances between WtH_m, WtH_B and WtH_10 showed that the differences were statistically significant in all size groups between all variables (Figure 2). The mean differences between WtH_m and WtH_B and between WtH_m and WtH_10 were statistically significant ($p < 0.01$).

Table 6 shows that there was no statistically significant ($p > 0.05$) relationship between measured WtHs and calculated WtHs. Considering basic anthropometric measures, WtH_m was related to hip girth ($p = < 0.001$), although the strength of the relationship was low. WtH_10 had functional relationship with body height (its derivate) and showed weak relationship to hip girth ($p < 0.01$). WtH_B was, next to bust girth, from which it was derived, related to the waist and hip girth (both $p < 0.001$). From the anthropometric measures, only the hip girth had statistically significant relationships with all WtHs.

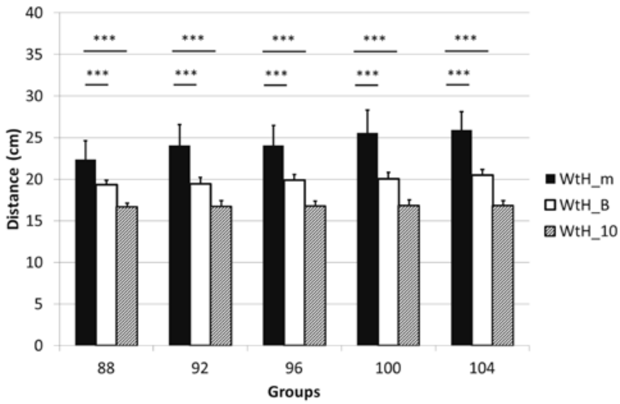

*Figure 2: Comparison between measured and calculated waist-to-hip distances for single groups. WtH_m - measured, WtH_10 - calculated from the body height, WtH_B - calculated from the bust girth, ** - P < 0.01, *** - P < 0.001*

Table 6: Pearson correlation coefficients

	BH	BG	WG	HG	WtH_m	WtH_1/10	WtH_BG
WtH_m	.124	.142	.025	.353***	1.000***	.124	.142
WtH_10	1.000***	.138	.185	.238**	.124	1.000***	.138
WtH_B	.138	1.000***	.767***	.647***	.142	.138	1.000***

Legend: BH – body height, BG – bust girth, WG – waist girth, HG – hip girth, WtH_m – measured WtH, WtH_B – WtH distances calculated from bust girth, WtH_10 – WtH distances calculated from body height ** - P < 0,01, *** - P < 0,001.

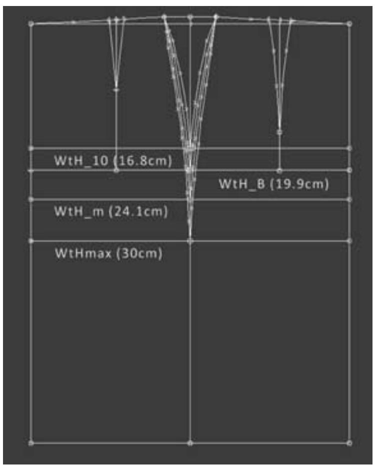

Figure 3: Effect of different WtH distances on the shape of the basic skirt pattern block in the size group 92. WtH_m – measured, WtH_B - calculated from bust girth, WtH_10 – calculated from body height

As an example, differently obtained WtH distances were put into the shape of the basic skirt pattern block for a single size to graphically present obtained differences (Figure 3). The differences resulting from different WtH distances affected the shapes of curved lines of the side seams and .consequently, the fit of the skirt above the widest hip level.

Discussion

The main findings of this study are that (i) measured waist-to-hip distance differed significantly from those obtained from the tables of the contemporary construction systems or calculated as a secondary measure according to these systems; (ii) the differences between measured waist-to-hip distance and other analysed waist-to-hip distances also increased as a size group increased; (iii) the range of measured waist-to-hip distances inside each size group was substantial (18–30 cm); (iv) the measured and calculated WtHs were not correlated.

The differences of WtH values among the analysed systems as well as among the size groups inside the systems were rather small, around 1 cm. It seems that different contemporary constructing systems follow similar approaches in setting waist-to-hip-distances. In contrast to them, the differences in measured WtH were much greater, up to 3.54 cm between the most distant size groups. The differences inside the size groups were even larger, more than 10 cm. This points to huge discrepancies between proposed and actual WtH values and raises questions regarding the suitability of the WtH values in contemporary construction systems to the observed population of young Slovenian females. The large variability in WtH_m raises a question of the introduction sub-sizes regarding waist-to-hip distance as seen with elongated or shortened trousers, sleeves, etc.

Calculated WtHs should be closer to individual characteristics of the subjects than table values since they originate from the measures obtained directly from the subjects' bodies. However, the variability in calculated WtHs was much smaller (because origin measures were divided by 10) than in measured WtH. The mean differences in distances between calculated and measured WtHs were even greater than with table values, and there were no relationships between measured and calculated WtHs. Therefore, the calculated also WtHs seem not to reflect the actual body dimension of young Slovenian females.

Differences in WtH distance will affect construction of basic skirt pattern block, as suggested in Figure 3. The amount to which the difference in the waist-to-hip distances affect the fit of the clothes is also dependent on the differences between the hip and natural waist girth of the wearer. The larger the difference, expressing a narrow waist in the front view, the more inappropriate it will be and will consequently cause poor fit of the close-fitted clothes. Since WtH_m was only weakly related to the hip girth and not to the waist girth, many combinations of WtH and girths distances are possible. It is not possible to derive WtH distance from any of measured body distance and relate it to the girth. They should both be measured to enable proper construction of a basic skirt pattern block.

The WtH distance is essential for every garment that covers the part of the body over hip level, i.e. trousers, dresses, blouses, t-shirts, coats, etc. The smaller clothes are to be more easily incorporated in the basic pattern cut (in other words, the fitter the clothes are), the more important the right value of waist-to-hip distance becomes. With classic fitted skirts or trousers, this measure is crucial to provide the proper fit of the garment. Even with blouses, the importance of choosing the real values of the waist-to-hip distance to create a better side seam curve together with the proper ease on the length level of the blouse is still high. With the basic trousers pattern construction, the body rise is the primary measure but the value of waist-to-hip distance still plays an important role to create the proper fit on the widest hip level of the wearer. The differences between values from the measurement tables, calculated ones from the equations and those gained with the anthropometric survey in the work presented here are too big to ignore and must be taken into consideration. Calculated WtH from the body height and WtH from the measurement tables cannot satisfy the proper fit of the clothes in the particular target group of young Slovenian female population.

Using real WtH distance is even more important in the made-to-measure business. When developing a basic skirt pattern block for the women with large WtH distances based on the measurement tables or calculated ones, the skirt would have a poor fit above the hip level. It would be too loose, and alterations would be necessary. The degree of the fit would be related to the proper selection of the curve shape of the side seam linked up with the curve shape of the hips and thighs in the front view of the selected body (Figure 3). The time and energy put in those alterations mean lost money and higher price of the product, which cannot help businesses to maintain competitive advantage on the market.

In the past, there was a tendency towards reducing the numbers of primary measures, because manual anthropometric surveys are time consuming and costly. However, in the previous decade, with the use of 3D body scanners, this has changed dramatically. Today, information about body dimensions can be obtained faster and in a more user-friendly manner. This makes it possible to obtain significantly more measures directly from the bodies, among which the waist-to-hip distance should be included. Additionally, large data bases of clothing 'customers' can be created, and clothing companies would have possibilities to extract from databases only those 'customers' critical for their business. In that way, the information of their real values would give them a competitive advantage on the market, while simultaneously giving consumers better satisfaction in the sense of proper fit of the garments on their bodies.

Conclusion

In conclusion, the values for hip-to-waist distances as proposed by different contemporary construction systems differ significantly from those measured in young Slovenian female population. Differences are smaller in small size groups (e.g. 88 cm) but became substantial and important in larger size groups. Furthermore, variability inside the size groups in the analysed population is immense and may significantly affect fit of the clothes. For this reason, it is suggested that the waist-to-hip distance be included as a directly measured parameter and not as secondary one taken from the tables or calculated from other measured distances or girths as now is the case.

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Povzetek

Cilj študije je bil primerjati izmerjene vrednosti kolčne globine mlade slovenske ženske populacije s tistimi iz sodobnih konstrukcijskih sistemov, da bi ugotovili, mere katerega konstrukcijskega sistema najbolj ustrezajo tej tržni ciljni skupini. V ta namen je bilo izmerjenih 156 študentk Univerze v Ljubljani (starost od 19 do 27 let). Rezultati so pokazali, da se izmerjena povprečna kolčna globina bistveno večja od tistih iz tabel konstrukcijskih sistemov ali izračunanih kot sekundarna mera po navodilih teh sistemov. Razlike med izmerjenimi kolčnimi globinami in ostalimi primerjanimi vrednostmi kolčnih globin so se z večanjem velikostne številke povečevale, variabilnost izmerjenih kolčnih globin pa je bila nekajkrat večja kot pri izračunanih. Ugotavljamo, da se vrednosti kolčnih globin, ki jih ponujajo sodobni konstrukcijski sistemi pomembno razlikujejo od izmerjenih vrednosti kolčnih globin mlade slovenske ženske populacije, zato predlagamo, da se ta mera vključi med neposredno merjene parametre v prihodnih antropometričnih raziskavah za potrebe oblačilne industrije.

KLJUČNE BESEDE: razvoj krojev oblačil, antropometrične meritve, kolčna globina, krilo, temeljni kroj

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