# Influence of waist height measurement on trouser length

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## Abstract
This study presents the results of a comparison between waist height (waist-to-floor) from contemporary construction systems (CCS) with the measured waist height (WH) of a young Slovenian female population with the aim of determining which WH presented in different CCS best fits the body measurement of market target groups. The study included 173 volunteers, young women aged from 19 to 27, students at the University of Ljubljana. The results showed significant differences between the measured WH and those obtained from the tables of the CCS. There was no trend in measured mean WH distances according to size groups; however, the differences among the size groups were statistically significant (greatest mean difference 2.54 cm, p=0.043). Another feature was substantial differences in the measured WH distances inside the size groups (with SD from 3.01 to 5.22 cm). All CCS gave lower values for WH than the mean ones measured in the study (up to -5.85 cm). To summarise, the measured WH distances of the young Slovene females differed significantly from the WH values as proposed by different CCS. When producing made-to-measure clothes, using the WH distance as a directly measured parameter for the trousers' pattern block development is suggested.

KEYWORDS: pattern construction, anthropometric measurements, waist height, trousers, basic pattern block

## Introduction
One of the most essential pieces of woman's clothing are long trousers. A very important feature of the trousers is their length, which should (among other requirements) match the length of the women's bodies from the waist down. Expectations of female customers are gradually increasing, which is why many producers and retailers sell many different lengths of trousers, which is crucial for the customer satisfaction as a good garment fit contributes to both the confidence and comfort of the wearer (Aleksander, Connell, & Presley 2005). Dissatisfaction with the fit is one of the most frequently stated problems with garment purchases in the ready-to-wear sector (Ashdown 2008). The fit of the clothes is closely linked with the body dimensions incorporated into the basic pattern blocks of clothes. In most trouser patterns, the length of the trousers is connected to the

*ANTHROPOLOGICAL NOTEBOOKS* 24 (2): 95–102.
ISSN 1408-032X

waist height (WH) measure (Aldrich 2004; Stiegler & Krolopp 1996; Haggar 1990). This WH value has a great influence on the fit of the trousers on standing level of the wearer. The aesthetics and functional characteristics of the new relationship between the body and the trousers are, therefore, influenced by WH measure. Although the measurement tables and basic block patterns of clothes in the ready-to-wear industry are usually established and fixed, they might not always be the best reflection of the target group's dimensions of the body (Ashdown & Dunne 2006; Podbevšek 2005). Since the sizes and proportions of human bodies are constantly changing due to various factors (Katzmarzyk & Leonard 1998; Starc & Strel 2011), there is a constant need to update the standards of fashion industry aided by 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).

In most contemporary construction systems (CCS), the WH measure is often the first measure needed in order to develop pattern blocks for trousers (Aldrich 2004; Stiegler & Krolopp 1996; Haggar 1990), and it is essential in the process of creating the proper fit of the trousers on the standing level of the wearer. The standard long trousers will look too short if the WH values incorporated in the basic pattern block are shorter than the actual ones; if they are longer, the trousers will crease around the ankles and start to drag on the floor. Satisfaction of the wearer with this fact depends on several factors (e.g., contemporary fashion style, personal preferences, etc.). However, this deviation would be more distinctive if the difference between the actual value of the WH measure and the one incorporated in the basic block pattern for the long trousers is bigger.

In contemporary construction systems, the influence of the WH measure on the fit of the standard long trousers on the body for different target groups is often overlooked. Most systems include the WH measure in their measurement tables without a description of the target group of the people for which they are designed. Values in those tables differ according to the system. The WH measure usually increases with the change of the bust (and hip) girth (Aldrich 2004; Haggar 1990; Joseph-Armstrong 1995), but in Müller's system WH values remain the same for all presented size groups (Stiegler & Krolopp 1996).

The question that arises when considering the differences of WH values in different CCS in their measurement tables is which WH distance fits best to the natural shapes and lengths of the different target groups of female bodies. The answer to this question can be obtained if these distances are compared with those from real subjects.

There is no common agreement on how to measure WH, and construction systems offer different measurement methodologies (Aldrich 2004; Stiegler & Krolopp 1996; Haggar 1990; Joseph-Armstrong 1995). What seems to be the most reliable way to select the proper methodology is to follow the process of basic pattern block development of the trousers. In most pattern construction systems, the WH distance is applied in the basic pattern block pattern as a vertical distance from the natural waist level to the ground. It is measured using the measuring stand at the side of the body, with the subject standing upright as suggested by the ISO 8559 standard (ISO1989), which was also used as a methodology of measurement in this study.

This study was conducted with the aim of comparing the WH distances from contemporary construction systems with the measured distances of young Slovenian women and determining the WH distance in numerous construction systems that best fits the body dimensions of that specific market target group .

# Method

## Sample

The anthropometric survey was carried out on 173 female students (age from 19 to 27 years) from the University of Ljubljana (Slovenia) who volunteered in the study. Subjects were selected to fit into a single body height group as suggested in SIST EN 13402-3 (SIST 2005) (from 164 cm to 172 cm). A division was made according to their bust girth measure, since it is the most important measure in the basic pattern development of clothes as well as size definition. Five major groups were formed according to SIST EN 13402-3 (SIST 2005). All participants were well informed about the procedures of the experiment. None of them had given birth.

## WH distances from the measurement tables

The WH distances were obtained from the measurement tables of the following CCS: Aldrich's system (Aldrich 2004), Haggar system (Haggar 1990), Joseph-Armstrong system (Joseph-Armstrong 1995) and the Müller system (Stiegler & Krolopp 1996; Stiegler & Krolopp1994) with their two measurement tables (Müller1 and Müller2). These systems (except the Müller system) followed the same measurement methodology for the WH distances as the one performed in the study. The values obtained from these tables were valid for the female population between 164 and 172 cm body height (here reported as 168 cm) and for selected size groups based on bust girth. The WH values from the Müller system (Stiegler & Krolopp 1996; Stiegler & Krolopp 1994) were also included in the paper, though their measurement methodology differs from the one in the study. The reason to do that was because the Müller system is the most commonly used pattern construction system in Slovenia and some parts of the Slovenian clothing industry use WH values from their measurement tables. According to the Müller system, WH (side length) is measured as the distance between the lower edge of the band, bounded round the natural waist, to the ground following the hip contour on the standing figure, measured with a measuring tape (Stiegler & Krolopp 1996).

## Anthropometric survey

During the measurement, the participants were standing on level ground in their natural posture with the feet together and with their centre of gravity distributed equally on both legs. Their heads were aligned with the Frankfurt line. During the measurement, they breathed normally with their abdomens relaxed with their arms hanging down freely 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 underwear and barefoot. The survey was performed in 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 a higher value with 0.5 cm accuracy.

The natural waist level (upper band) between the top of the hip bones and the lower ribs where the girth is the smallest according to ISO 8559 (ISO 1989) and hip level (lower band) round the buttocks at the level of maximum circumference according to ISO 8559 (ISO 1989) were first selected and marked with a 2 mm wide elastic band (Figure 1).

The bands were adjusted around the body so that the ellipsoid levels of the waist and hip were perpendicular to the longitudinal axis of the body. None of the bands did compressed the soft tissue of the body; therefore, the values of the measurements were not affected.

After that, body height, waist height, bust girth, and hip girth were measured on the standing figure. The measurements of body height (BH) were performed with an 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. The measurements of WH were also performed with an anthropometer at the side of the body as the vertical distance between the upper edge of the string around the natural waist level and the ground, measured on the standing figure.

Bust and hip girts (Figure 2) were measured with a dimensionally stable tape-measure. The bust girth (BG) was measured as the maximum horizontal girth with the subject standing in her natural posture and tape-measure passed across the nipples but adjusted around the body in a way that the ellipsoid level of the bust girth was also perpendicular to the longitudinal axis of the body. Hip girths (HG) were measured precisely below the elastic bands on the marked hip levels (Figure 2).

## *Statistical analysis*

The participants with the body height from 164 cm to 172 cm were analysed, arranged into size groups according to their bust girth in the range of 4 cm, as suggested in SIST EN 13402-3 (ISO 2005). Five size groups were formed with the bust girths 80 cm (from 78.5 to 82 cm), 84 cm (from 82.5 to 86 cm), 88 cm (from 86.5 to 90 cm), 92 cm (from 90.5 cm to 94 cm) and 96 cm (from 94.5 cm to 98 cm).

For each group, basic statistical parameters of the analysed variables were calculated. Statisticaly significancant differences among the size groups for single variables were first tested with ANOVA and then with post-hoc T-tests for single pairs of size groups (Bonferroni correction). A Pearson correlation coefficient was calculated between selected measures. Additionally, differences between mean values of size groups and corresponding values from different construction systems were calculated. Results were statistically processed with SPSS (version 22, IBM SPSS, New York, USA). Alpha error was set to 5% (two-tailed).

## Results

Waist heights (WH) obtained from different measurement tables of CCS are presented in Table 1. Among the systems, the Haggar system gave the lowest values for all size groups while the Müller system provided the greatest values for size groups under 88 cm bust girth and the Armstrong system for size groups over 88 cm bust girth. Differences among systems were substantial: from 1.9 cm for women with a bust girth of 96 cm, up to 5.6 cm for women with a bust girth of 80 cm. In most of the presented systems, the WH values increased with increase of the bust girth, the most in the Haggar system, where distance changed linearly by 1.3 cm between the sizes. In the Müller system, the WH values stayed the same in all size groups.

The results of the measured WH are presented in Table 2. The largest difference between the means of the size groups was 2.54 cm. ANOVA showed that the mean values among the size groups were statistically significantly different ($p = 0.043$). Among all the groups' pairs, only the difference between the size groups of 88 cm and 92 cm was statistically significant ($p = 0.033$). The variability inside the size groups was much larger than between the groups, since standard deviations in the size groups were greater than 3 cm in all size groups. The differences in mean values did not systematically increase or decrease as the bust girth increased.

The correlation coefficients between measured variables in the present study are presented in Table 3. Although correlation coefficients of WH with BH and HG were statistically significant ($p < 0.05$), the magnitude of relationship was small in both cases (0.435 and 0.154, respectively).

Each construction system was different from the measured WH in its own way. The greatest differences were observed in the Haggar system (between -5.85 cm and – 1.73 cm) and the smallest in the Müller system (between -2.26 cm and 0.28 cm). In all construction systems, the smallest differences were observed in the size group of 88 cm.

## Discussion

The main findings of this study were that measured WH distances differed significantly (up to 5.85 cm) from those obtained most of the tables of the contemporary construction systems; measured WH distances did not increase or decrease as the size group increased, as with most of analysed contemporary construction systems; the range of measured WH distances inside each size group was substantial (SD from 3.01 to 5.22 cm); all compared systems gave lover values for WH than the measured ones.

The differences in WH distances among the analysed CCS were noticeable with 1.9 cm in the largest size group and become substantial with the decrease of the bust girth, when they reached 5.6 cm. For producers of trousers, which WH distance to choose for their specific target groups of customers in the trouser pattern block development processes is critical. In presented CCS, the WH distances increased as the size group increased (except in the Müller system). This shows that different CCS follow a similar approach in setting their WH distances. In contrast to them, the measured WH distances did not follow any trend, and the mean distances did not differ significantly among the size groups nor did they show any tendency of increasing or decreasing as the size group increased.

Measured mean WH values were higher than all the WH values in the compared construction systems. They seem to be closer to those within the Müller system (which is mostly used in Slovenia), though it uses the measurement methodology that should provide even higher results than the measured ones. Specifically, in the survey, this is the only system that measured the WH distance between the lower edge of the band, bound around the natural waist, to the ground following the hip contour on the standing figure (Stiegler & Krolopp 1996). All other CCS measured WH as a vertical distance between the natural waist line and standing (ground) line (waist to floor).

All these points lead to significant discrepancies between proposed and actual WH values and bring into question the suitability of WH values in contemporary construction systems' tables for the observed population of young Slovenian females. Differences in values strongly affect the length of the trousers on the wearer. The range inside the size groups in measured WH values was large (SD from 3.01 to 5.22 cm), which raises a question of introducing the sub-sizes upon WH.

Not only important in the process of developing basic trousers pattern blocks in the sense of proper fit, the WH distance is also essential in designing garments that cover the whole length of the legs to the ground, such as long skirts, long dresses, coveralls, and similar.

In made-to-measure businesses, the importance of selecting the real values of the WH distance is even more important. The survey showed that the values of the WH distances of the participants vary significantly. In most cases, CCS values were 0.5 to 1 standard deviations below the measured mean WH distance, which mean that some 70 to 84% of the analysed population had larger WH distances than estimated with most of CCS. For example, a basic trousers pattern block for women based on SSC data were designed, the trousers would be too short for most of the population and would not cover the whole length of the legs. This would strongly influence the appearance of the wearer. Alterations would not be possible because of the lack of textile on the floor level. This problem would be smaller if the real WH distance would be shorter than that from the CCS incorporated in the basic block pattern since it would cause only poor fit of the trousers on the described level. Alterations would still be necessary. Time and energy put in those alterations means lost money and raising the prices of the product, which cannot help businesses to maintain competitive advantage on the market. This is another reason to include the WH distance into the anthropometric surveys as one of the important measures that influence the shape of the pattern block and consequently the fit of the clothes.

Due to the fact that manual anthropometric surveys are time consuming and costly, there has been a predisposition to decrease the numbers of primary measures. However, this problem proved to influence sales and became so significant that companies started to develop clothing patterns with the help of technological tools, such as 3D body scanners and CAD systems to assist a made-to-measure process in order to improve apparel fit (Chin-Man 2007). With the help of 3D body scanners, the information about body dimensions can be obtained faster and in a more user-friendly manner. This gives possibility to obtain significantly more measures directly from bodies, among which waist height distance should always be included. With the introduction of 3D body-scanning technologies, many contemporary researchers start to investigate different target groups of customers and determine new body dimensions that are important for the better fit of clothing basic blocks to their bodies (Wang, Xu & Wang 2017; Liu, Wang & Istook 2017;

Stjepanović et al. 2011). Additionally, large databases of clothing "customers" worldwide should be created to give different clothing companies possibilities to extract from databases only those "customers" important for their business. In that way, the information of their real body measures would give them competitive advantage on the market due to the better fit of their clothes to their customers.

## Conclusion

The waist height distance as measured in a young Slovenian female population differed from the ones proposed by different contemporary construction systems. The measured WH distances showed no significant differences in mean values among the size groups while most of the systems systematically increased WH with increasing bust girth. The differences were substantial and could significantly affect the fit of trousers on the standing level of the wearer, especially because the possibility of alterations are limited due to the too short length of the trousers. When producing made-to-measure clothes, including a measured WH distance for pattern block construction instead of those from the tables of construction systems is recommended.

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## Povzetek

V študiji so predstavljeni rezultati primerjave višine pasu (VP) dobljenih iz sodobnih konstrukcijskih sistemov z izmerjeno višino pasu pri mladih slovenskih ženskah, da bi videli, če mere na osnovi konstrukcijskih sistemov ustrezajo telesnim meram te izbrane ciljne tržne skupine. Študija je bila opravljena na 173 prostovoljkah, starih od 19 do 27 let, študentk na Univerzi v Ljubljani. Rezultati so pokazali pomembno razliko med izmerjeno višino pasu in vrednostmi VP iz večine tabel mer sodobnih konstrukcijskih sistemov. Pri izmerjenih VP ni bilo opaziti povečanja ali zmanjševanja povprečnih vrednosti izmerjenih VP s povečevanjem velikostne številke, čeprav so bile razlike med njimi statistično značilne (največja povprečna razlika 2,54 cm, p=0,043). Naslednja značilnost je bila izrazit razpon vrednosti VP znotraj vsake velikostne številke (SD od 3,01cm do 5,22 cm). Vsi primerjani konstrukcijski sistemi so tudi ponudili nižje vrednosti v velikostnih razredih od povprečij izmerjenih v študiji (do -5,85 cm). Ugotavljamo, da se mere VP mladih slovenskih žensk bistveno razlikujejo od mer VP, ki jih predlagajo različni konstrukcijski sistemi. Zato predlagamo, da se pri izdelavi oblačil po meri uporabi VP kot neposredno merjen parameter pri razvoju temeljnega kroja hlač.

KLJUČNE BESEDE: razvoj krojev oblačil, antropometrične meritve, pasna višina, hlače, temeljni kroj

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