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DEVELOPING A SUSTAINABLE CHILDRENSWEAR SIZING SYSTEM: BODY SIZE, SILHOUETTE SHAPE AND CLOTHING KEY DIMENSIONS

Marzie Hatef Jalil*, Musdi Shanat

Faculty of Applied and Creative Arts, University Malaysia Sarawak, Malaysia

Abstract. Inconsistent children's garment sizing may cause fit issues, leaving youngsters unable to find clothing in the correct size or recognise what size fits their body form. This research attempts to find sustainable solutions to design issues regarding non-fitting children's clothing that involve reducing post-consumer waste. Through this concept, children's clothing can be customised based on the garment type, as well as the child's body features and silhouette. By employing the patternmaking system M. Müller & Sohn technique, patterns were created using Computer-Aided Design to enhance flat patterns of basic silhouettes. Patterns were developed and used to dress virtual mannequins with CLO3D, a three-dimensional virtual sewing and try-on software. CLO3D system realizes virtual fitting, including three-dimensional body modeling and a three-dimensional virtual sewing fitting map. According to the international size charts, the findings of this study demonstrate that different silhouette shapes often do not follow regular market sizes, while children's sizes can be recognised effectively by understanding their body size, age, height, and weight. Therefore, children's clothing can be customised with a specific height range, body size and silhouette shape. Henceforth, when designing and purchasing children's clothes, accurate information could prevent the growth in post-consumer waste arising from the production of children's clothing and be an essential step to achieving sustainability in the apparel industry.

Keywords: *Childrenswear, sizing system, post-consumer waste, body size, silhouette shape, sustainability, apparel industry.*

Corresponding Author: *Marzie, Hatef Jalil, University Malaysia Sarawak, Malaysia, Tel.: +6082581346, e-mail: hjmarzie@unimas.my*

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1. Introduction

Schofield (2007) confirmed that disconnections between anthropometric measures and children's size charts contributed to discrepancies between the clothes and the children's body size and silhouette shape. Saaludin et al. (2020) investigated visualising the size matching recommender system, which provides a reference for parents who buy children's clothes by recommending the correct size according to particular brands. However, each child's growth pattern varies, and most clothing sizing systems used by clothing brands come from industrialised countries and are not applicable in some developing countries (Yusuff, 2016). Each brand's size reference chart employs different height, weight and waist measurements. Despite studies showing that different genders and age groups have distinct silhouette shapes (Yusuff, 2016), several businesses have ignored these differences while creating children's apparel.

Dove (2020) showed that the dearth of children's pattern makers meant that fitting prototype children's clothing was rated the most important future competence for technical designers. The ability to properly fit a garment has also been a skill shortage frequently exhibited by entry-level designers (Dove, 2020). Inconsistent brand sizing

and confusing size codes are also concerns. Sizing and size coding are essential to consumer satisfaction with children's clothes (Otieno, 2000). Winks (1997) stated that age would not be the best indication of children's sizes since it does not affect physical size or shape. Hence, children's clothing manufacturers need to focus on made-to-measure designs in the mass and domestic production of children's clothes, while they also need to consider gender, body size and specific measurements based on the clothing key dimensions, which have not previously been investigated. In addition, this study has utilized a virtual fitting system to investigate fitting clothes for different children's silhouette shapes. As virtual fitting technology has grown and improved, 3D virtual fitting technology has received attention in recent studies (Huang & Huang, 2022; Wang & Liu, 2020). CLO3D is one of the well-known fitting programmes made by the CLO Company in South Korea. It is a simulation-fitting solid programme with full functions that is easy to use and quick to run. This programme was used in this study for simulation and fitting purposes. Moreover, this study investigated significant clothing key dimensions involved in making basic patterns in children's clothing, thus helping clothing designers to operate effectively. So, this research applied the patternmaking system. Müller & Sohn technique to create basic pieces. In the Müller Pattern Making System, which Michael Müller developed for Germans, the basic measurements are taken from the body directly. Other measures are calculated during pattern drawing using these measurements. Hereafter, a customisation concept enabling buyers to explore which sizes or designs they want to purchase may help to reduce post-consumer clothing waste and overconsumption problems. This research will also significantly impact consumption and waste management, as children will be able to wear specific items that fit far better and for much longer than previously.

2. Literature Review

2.1. Custom Children's Clothing and Difficulties

Size changes can affect the choices made over many features, such as apparel and footwear. Saptari et al. (2013) stated that poor product design for children might lead to the development of musculoskeletal disorders and health problems. The effect of poor product designs that do not meet the children's dimensional and safety requirements may be experienced by the children when they grow up. Clothing designers should be cognisant of children's quick growth since this will affect the children's bodies and clothing sizes (Bari *et al*., 2015). Bari et al. (2015) stated that great clothing designers recognise that children grow rapidly. Bougourd and Treleaven (2020) stated that no complete review had been developed from anthropometric body measurements, so most clothing firms used "ready-to-use data" such as body size charts.

Moreover, Bezerra et al. (2017) believed that children's clothing lacked an anthropometric assessment to enable it to fit the body and increase comfort. Disconnections between anthropometric measures and size charts have contributed to disparities between clothing and the customers by whom the clothes are intended to be worn (Schofield, 2007). Hence, from the perspective of child product designs, there is a serious need to consider the anthropometric data of children to lessen the risks of ergonomics hazards (Ismail *et al*., 2009). Therefore, the definitions and anthropometric data among children should be considered for children's clothing products that this study has applied anthropometric data from Pheasant and Haslegrave (2018) and the data of patternmaking system Müller & Sohn (1994). For this research, anthropometric

dimensions were chosen based on three criteria: size, age range and sex. In line with this problem, a major complaint is that garments do not fit properly (Bezerra *et al*., 2017). According to a study by Bezerra et al. (2017), two-year-old children often wear clothes labelled as size four or even size six, which are expected to be used by children of four to six years old. The industry's current measurements tables do not correspond to the anthropometric measurements of today's children (Bezerra *et al.*, 2017). Bari et al. (2015) discovered that several forms of anthropometric measurement data were being used to develop clothing sizes. Bari et al. (2015) stated that height measurement is an essential aspect of identifying sizes; however, it is not the only parameter. Children's sizes that are determined by height measurement are augmented by weight measurement.

In addition, a person's weight affects the measure of their circumference. Therefore, children's apparel designers should note several crucial key dimensions of youngsters, such as their height and weight, as well as their chest and waist circumferences in combination. These control measures must be accurate to ensure that the exact dress size is produced (Bari *et al.*, 2015). It is challenging to make clothing for various body sizes and silhouette shapes, particularly for growing youngsters (Shaharuddin & Jalil, 2021a). Since the mass production of children's clothing began in the early 1900s, the sizing terminology issue has been a source of confusion (Guppy, 1978). Choosing the proper garment fit is critical for children since it is directly associated with the body's conformance to clothing, which is especially important because children often engage in vigorous everyday activities. Children grow up rapidly in different patterns (Harun *et al*., 2019). Hence, Gribbin (2014) pointed out that a study focusing on children's clothing would be useful because children outgrow their clothes far more quickly than adults. Therefore, the fit may determine their clothes size.

Many studies have been conducted to determine levels of parental satisfaction with the fit and sizing of their children's apparel. These elements have been identified as two of the most important reasons for consumer dissatisfaction, particularly with ready-to-wear products (Kim *et al*., 2015; Schofield, 2007). Since children frequently vary in size and silhouette shape, the longevity of children's clothing is regarded as being less important than that of adult clothing (Shaharuddin & Jalil, 2021a). Allakulov et al. (2022) stated that between eight to ten years of age, the figure partially stabilises due to a decrease in the growth intensity; in other words, the child "gets masculine": the bone base develops, the muscles strengthen, the figure becomes slimmer as the legs lengthen, the abdominal bulge disappears, and the waist is outlined. However, Bezerra et al. (2017) believed that anthropometry for children's clothing has many difficulties and limitations, and standard sizes and general statements can not be generalised to all children. Moreover, Allakulov et al. (2022) stated that the main silhouettes of clothes for girls seven to eight years old are straight and extend from the waistline. Hence, it is better that dresses for girls of this age feature a high waistline. However, in the silhouette shape at this age, the contours of the waist are not yet sufficiently defined; this depends on the individual child's shape (Allakulov *et al*., 2022). According to their research findings, over half of the youngsters did not fit into the clothes that had been designed for their age. Two children were wearing clothing of an appropriate age size on the upper halves of their bodies, but their clothes did not fit on their bottom halves.

In addition, Zakaria et al. (2008) stated that children must wear clothing that fits appropriately since this factor is connected to, first, the clothing's ability to adjust to their bodies and, second, the sustainability approach. A preliminary study by Saaludin et

al. (2020) on parents' online shopping satisfaction revealed that parents must take risks with online shopping because their children cannot try on clothing before it is purchased. Tongue et al. (2010) showed that most parents believed that varying the leg lengths within the clothing that is otherwise the same size would make the clothes stretch more than usual. Moreover, making sizes more generous and maintaining more significant grades between the sizes could assist in solving the fit concerns from which children's clothing is known to suffer (Jalil & Shaharuddin, 2021). Making accurate garment patterns is also important. Associating garment patterns with silhouette shapes is necessary to provide fit and satisfaction. Various pattern-making methods are used in the apparel sector since the anatomies of people from different countries vary, while separate pattern preparation stages are employed in other systems (Tama & Öndoğan, 2014). However, these systems are also widely used in countries that lack pattern-making systems.

2.2. Children's Clothing Size Chart and Sustainability

There is a critical need to develop an adjustable table with body dimensions for various commercial sizes related to children's ages when incorporating sustainable design in clothes production. Therefore, the absence of research on children's body measures within sustainable clothing production underlines the relevance of this study. Bezerra et al. (2017) discovered that during their research undress and dress process, the neck collars of t-shirts and sweaters were too small for some children's heads even if they were the same age. It was also perceived that, generally, trouser leg widths were identically fair, but this hindered children's constant movements, blocked their blood circulation and hampered their leg movement. For this reason, some children requested help to undress and dress when wearing trousers. The most up-to-date size charts available are based on anthropometric measurements. Each size must be identified and analysed to assist potential clients to recognise a good fit (Jalil & Shaharuddin, 2021).

However, the fundamental difficulty with all size charts and anthropometric data is that children's bodies constantly change. Hence, obsolete measurements result in a wide range of shapes and sizes amongst children (Pechoux & Ghosh, 2002). The study by Saaludin et al. (2020) concluded that purchasing clothes of the wrong size necessitated time to return and exchange them; the clothing was frequently considered unwanted and went to post-consumer waste. Fit and sizing difficulties have been addressed in several ways, including 3D virtual try-ons that help clients better understand their body measurements (Balach *et al*., 2020). Different approaches, such as "Virtusize" and "True-fit," have been employed by various start-up enterprises to aid clients in selecting garment sizes (Edmir, 2017).

Moreover, some companies use online consumer body type history to recommend the next purchase size. The online company 'Virtusize' allows buyers to determine the proper size based on measurements and clothing descriptions. While businesses and mass production have exploited this platform, it has not been gradually introduced into the domestic production of children's clothing. As previously mentioned, children's clothing always involves fit issues because their bodies range widely in height and weight at different ages due to genetics, diet and other environmental effects (Tongue *et al*., 2010). To avoid bad publicity, returns, complaints and decreased sales owing to poor fit, retailers should constantly prioritise their clothes' quality and fitting size parameters.

Park and Kim (2016) investigated the parametric silhouette shapes of children aged three to eleven years old; the results showed that the silhouette shapes of children of the same age vary according to several factors, such as changes in stature and body weight. Hence, the standard size of children can change according to the form/system used; therefore, fitted clothes cannot be chosen by age and stature without consideration of body mass. As children grow, a disproportionate amount of fat settles on their stomachs. Hence, the silhouette shape of most children has been classified in the previous literature, namely as the spoon, rectangle and oval (Gribbin, 2014; Park & Kim, 2016; Tama & Öndoğan, 2014). The term spoon refers to the circumferential difference in the bodice and bottom part, the bust-to-waist ratio is lower than the bottom part, and the hip-to-waist ratio is high. The term rectangle means the bust and hip measurement are fairly equal, the bust-to-waist and hip-to-waist ratios are low, and there is no discernible waistline. Finally, oval means the average of the stomach, waist and abdomen measurements are less than the bust measurement. Moreover, modern technology, including digital virtual humans and virtual garments, has significantly impacted the current apparel industry. Virtual simulation technology enables the visualisation of a 3D virtual garment on a virtual avatar so that garments can be tried on using virtual mannequins (Lim & Istook, 2010).

The current paper used the patternmaking system M. Müller & Sohn technique to create basic pieces, which was developed by Michael Müller in Munich, Germany, in 1891 that patterns are drawn by a combination of basic blocks (Kılıc, 2011). Consequently, this study aimed to enhance the custom size charts for children's clothing in a slow fashion to potentially address the issues regarding children's bodies on a general level, either domestically or industry wide. This research aimed to generate updated standard measurement tables that would provide the necessary information to undertake the pattern creation process with more precision, thus offering improved comfort for children and reliable data for industrial use.

3. Methodology

The accomplished method for this study is categorised into three stages as follows.

3.1. Digital Design Patterns of Basic Children's Garments

The first phase focuses on digitally making patterns of basic child's garments using Computer-Aided Design to enhance flat patterns. In the apparel industry, the system to make any new garment design is first to prepare the basic garment patterns; thereafter, each new garment pattern will be extracted from modifying basic garment patterns. In addition, according to Müller & Sohn (1994), all children's clothes designs are created by modifying basic garments, including *basic shirt, basic skirt, basic trouser* and *basic dress*. Hence, in this study, basic garment patterns will be designed primarily. In addition, the current pattern-making systems have developed according to the common kid's silhouette shape in the community, and no more consideration has been applied to the particular silhouette of children. Therefore, this study utilized common kids' silhouette shape measurements for the first phase to create patterns of basic garments. As mentioned before, the patternmaking system by Müller & Sohn (1994), a German and well-known pattern-making technique, was used to enhance the optimised children's flat patterns of basic garments in this study. The output of this phase is the

digital flat patterns of basic children's garments based on the common kid's silhouette shape with existing measurements.

3.2 Three-Dimensional Virtual Fitting Technology and Fit Map

CLO3D is a three-dimensional clothing design CAD system that combines panel sketching and virtual fitting functions. It can create a human model, 2D model, 3D clothing virtual stitching, fabric simulation, and dynamic virtual display. By editing the size of the virtual mannequin, silhouette shapes can be changed, which is one of the purposes of this study. Therefore, created patterns from the first phase were used to dress virtual kids' mannequins with different body sizes, silhouette shapes, and similar height, age and weight for the second phase. In this phase, four common silhouette shapes (standard, spoon, oval and rectangle) were developed by changing measurements of the upper (chest and bust area), middle (waist and abdomen area) and lower (hip area) parts of the virtual kid's mannequin. Each garment was investigated regarding simulation, design, and fitting in different kids' silhouette shapes through 3D virtual sewing with CLO3D software.

3.3 Developed Children's Size Chart and Clothing key Dimensions

In the last phase, after simulation and virtual fitting assessment via Fit Map technology, the clothing key dimensions of each basic children's garment were recognized and modified in the existing children's size chart, as shown in Table 1. In the CLO3D software, the Fit Map shows how tight the 3D Garment is. So, the area that you cannot wear is shown in red, while the very tight area is shown in orange, and the slightly tight area is shown in yellow. When the pressure test is applied, it shows how the pressure is distributed and where the contact points are. This shows how comfortable the clothing body is. When a person dresses, the pressure on the body can show the level of stress in the clothes, which is indicated by the colour. The higher the tensile strength and the higher the clothing pressure, the bigger the red area is illustrated. In the CLO3D simulation, after fixing the issues in the clothing, it shows that the red area gets smaller, and the green area gets bigger.

Based on the patternmaking system M. Müller & Sohn technique and virtual fitting assessment via Fit Map, eight factors - bust (B), waist (W), hip (H), sleeve length (S), centre length back/front (CB), crotch length (CL), waist to hip (WH) and shoulder-length (SH) were frequently changed according to children's body sizes and silhouette shape; however, the garment's type and clothing key dimensions have the critical role. Hence, for each garment, the significant and effective key dimensions in pattern making based on different body sizes and silhouette shapes are achieved and shown in Table 1 (Müller & Sohn, 1994). Moreover, the fabric chosen for the simulation study was cotton knit, which is the most applicable for children's garment production (Shaharuddin & Jalil, 2021b), with a thickness of 0.56 mm and a weight of 237 gr/m^2.

4. Findings and Discussion

The child's body can be divided into three important sections: upper (chest and bust area), middle (waist and abdomen area) and lower (hip area). The upper and lower parts are more significant than the middle (Figure 1-a). With the spoon's silhouette shape, the middle and lower parts are slightly bigger than the upper part, resembling a spoon (Figure 1-b). The next type is the oval silhouette shape, as shown in Figure 1-c; the middle part is larger than the upper and lower parts and resembles an ellipse.

Finally, children with a rectangular silhouette shape have equally sized upper, middle, and lower parts, like a rectangle (Figure 1-d). As mentioned before, this study focuses on the basic children's garments, how they change based on differences in silhouette shape and the effective parameters and key dimensions used for each garment.

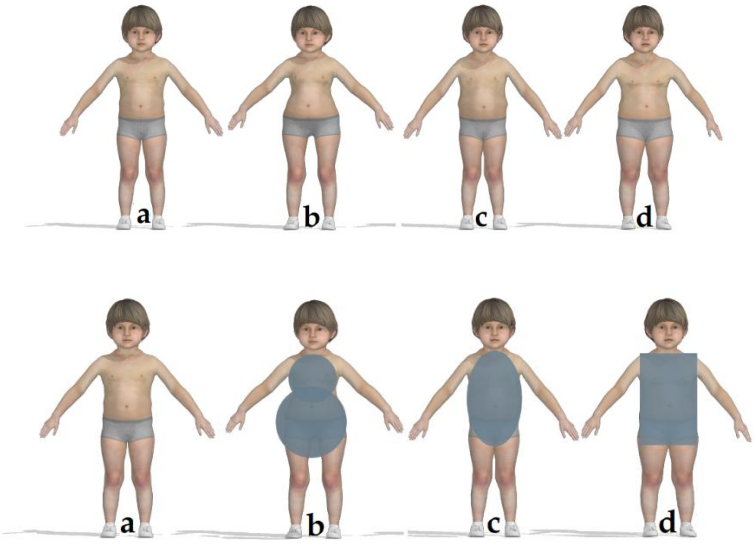

Fig. 1. Comparison of four different silhouette shapes: a: standard, b: spoon, c: oval, d: rectangle

Basic Skirt and Key Dimensions. According to the skirt pattern-making techniques, children are categorised based on an undefined scale due to the various measurements of three parts: WH, W and H. It means that two children of the same size, age, height range and weight (according to a standard chart shown in Table 1) may differ in any of these key dimensions because of their specific silhouette (Bezerra *et al.*, 2017). The basic skirt's flat pattern-making panels are shown in Figure 2-top, highlighting the key dimensions. If both children are four years old, but one has a spoon silhouette shape, W and H will be different, and, due to changes in the middle part of the body, WH would also differ. The same applies to the oval shape, where W and WH are different. Hence, these three measurements are essential in making children's skirts, whether *A-line*, *gathered* or *yoke* skirts.

As shown in Figure 2-bottom, a basic skirt in the standard silhouette shape is fitted (Figure 2-a). The red spots show that this item cannot be worn at all since it is smaller than an actual child's silhouette shape; moreover, the yellow spots show that it can be worn but will be too tight and may damage a child's health. Hence, no red spots and yellow spots are present for children with standard silhouette shapes; however, for other silhouette shapes, the item does not seem to be suited and strengthened for certain body parts (Figure 2-b, 2-c and 2-d). For instance, the fabric stretches in an oval shape since there is a tummy in the waist area (Figure 2-b), and the child would not be comfortable wearing this type of garment. In terms of the spoon silhouette shape (Figure 2-d), the number of red spots is greater than for the other types, so children can no longer wear this skirt. The other skirt types should produce similar results. However, some skirts have loose silhouettes, such as gathered or A-line types; children with rectangular and oval silhouette shapes may experience discomfort in the waist region unless an elastic band is used that does not irritate the waist.

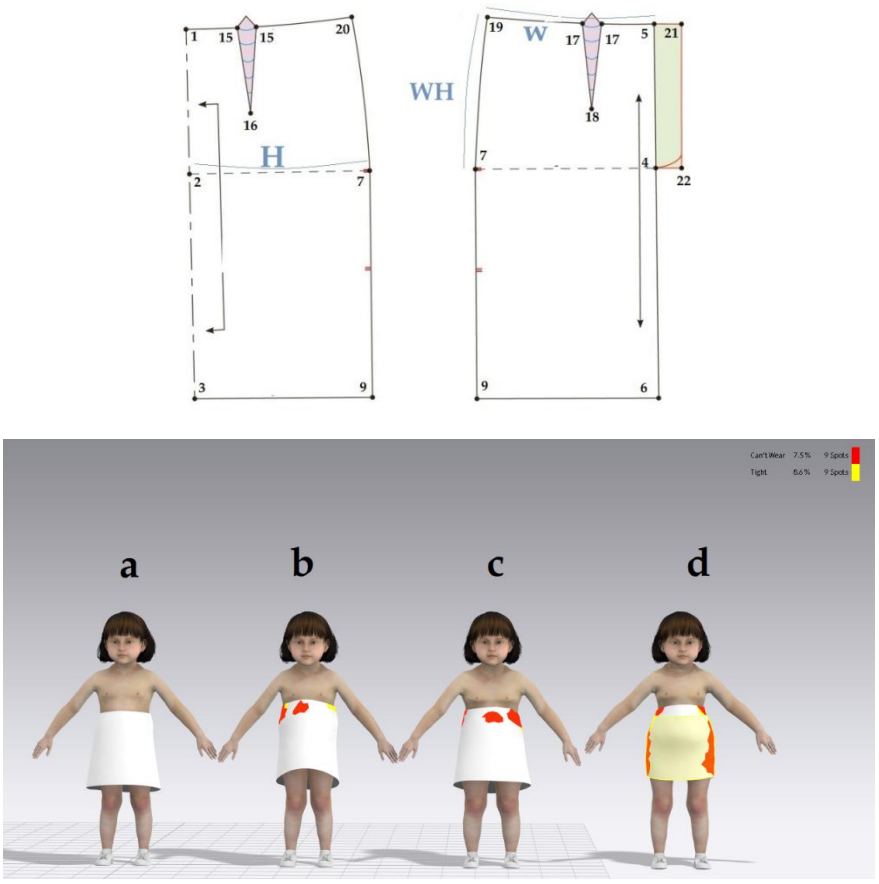

Fig. 2. Skirt flat pattern and key dimensions in measurement (top); Simulation of a skirt for silhouette shapes: a: standard, b: oval, c: rectangle, d: spoon (bottom)

Basic Trouser and Key Dimensions. Similar to making trousers, children are categorised on an undefined scale since they have different measurements in four key dimensions: W, H, WH and CL. The flat pattern-making panels of basic trousers are shown in Figure 3-top, highlighting the key dimensions. W and WH may differ in those of the same age, but in oval-shaped bodies, W, H and especially CL will vary. Moreover, the same is the case for the spoon silhouette shape, but WH also will differ with this silhouette form. Hence, these four measurements are essential key dimensions in making basic trousers, whether they are *skorts*, *jeans*, *shorts*, or another type.

As shown in Figure 3-bottom, basic trousers for the standard silhouette shape are fitted (Figure 3-a); however, they seem inappropriate and strengthened in some body parts for other silhouette shapes due to the number of red and twelve yellow spots (Figures 3-b, 3-c and 3-d). For example, the rectangle has a straight-line shape in the WH part and looks shorter than usual, the fabric is tight (Figure 3-c), and the child will not find it convenient to wear this kind of garment. Other trouser types are the same because the trouser silhouette is the same; they have different lengths and decorations. Children with a spoon and oval silhouette shapes (Figure 3-b and 3-d) may experience discomfort in the waist, especially in the crotch and hip region (Figure 3-d); the garment will be too tight, with the three red spots meaning that children cannot wear it or move quickly unless the stretchy fabric has been chosen.

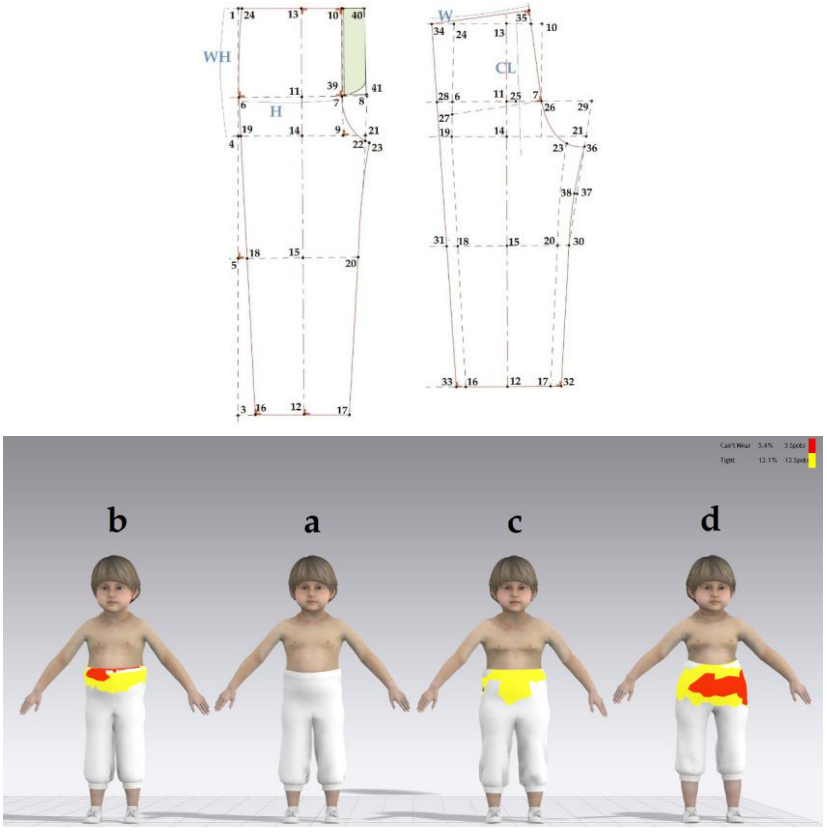

Fig. 3. Trousers flat pattern and key dimensions in measurement (top); Simulation of trousers for silhouette shapes: a: standard, b: oval, c: rectangle, d: spoon (bottom)

Basic Shirt and Key Dimensions. Children are categorised on an undefined scale when blouses, tops and shirts are made since different measures of six key dimensions are used: B, W, H, CB, A and SH. The basic shirt's flat pattern-making panels are shown in Figure 4-top, highlighting the key dimensions. If two children are four years old, the one with an oval silhouette shape has differentiated measurements in W and CB. If two children are the same age, but one has a rectangular silhouette shape, W, SH, S, and B will be different. Hence, these six key dimensions are essential in making a basic shirt, whether it is a *raglan* shirt, a *blouse* or a *jacket*. As shown in Figure 4-top, the basic bodice in the standard silhouette shape is fitted (Figure 4-a); however, this seems inappropriate and strengthened in some body parts for other silhouette shapes, with seven yellow spots and nine red spots. For example, children with a rectangle silhouette have a boxy silhouette, so they will not find it convenient to wear this kind of garment and cannot move their arms quickly (Figure 4-c). The bodice design is slightly different from other garment types since most key measurements are involved in this part; hence, all the vital factors - such as B, W, H, CB, WH and SH - change with the silhouette shape. As shown in Figure 4-b, SH is tight for children with an oval silhouette shape and cannot be worn because the neckline contains some red spots in the neckline, showing that this is not an excellent choice to wear. Unless the shape is loose, the fitting purpose is not a concern. Children with a spoon silhouette shape (Figure 4-d) may experience discomfort in the waist and armhole parts, especially in the hip region, as too many yellow spots are present here; the garment will be too tight, and children cannot move quickly unless the stretchy fabric has been chosen.

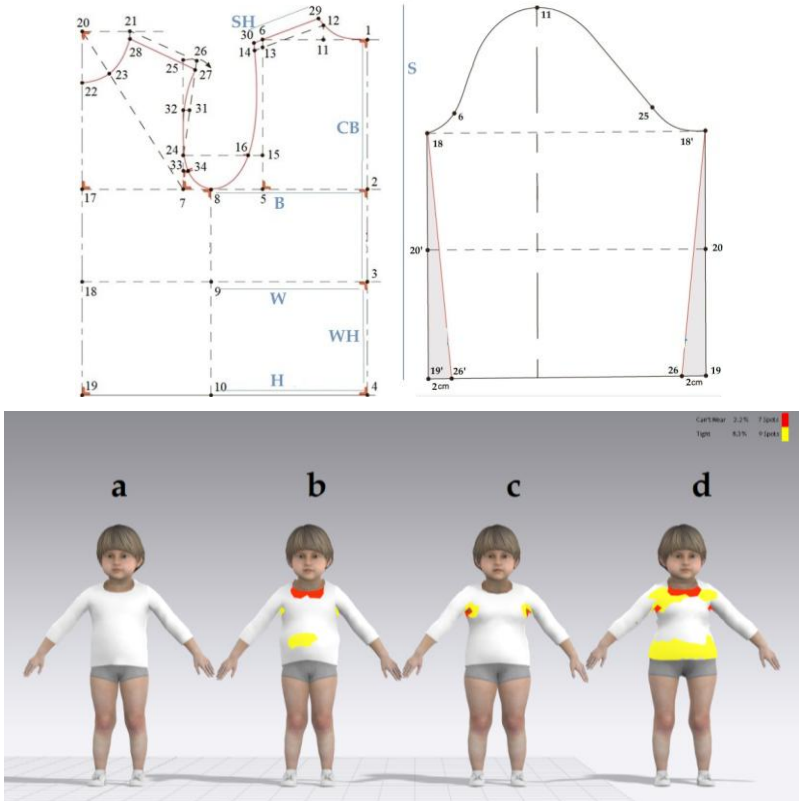

Fig. 4. Shirt flat pattern and key dimensions in measurement (top); Simulation of a shirt for silhouette shapes: a: standard, b: oval, c: rectangle, d: spoon (bottom)

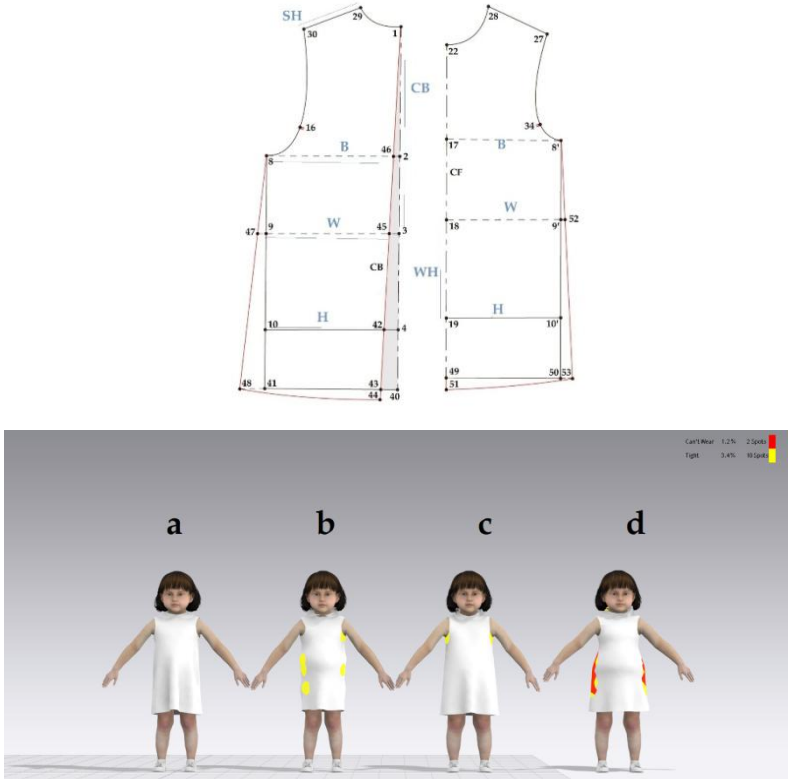

Fig. 5. Dress flat pattern and key dimensions in measurement (top); Simulation of a dress for silhouette shapes: a: standard, b: oval, c: rectangle, d: spoon (bottom)

Basic Dress and Key Dimensions. Making a dress follows the shirt patterns plus another parameter, WH. The flat pattern-making panels of a regular dress are shown in Figure 5-top, highlighting the essential dimensions. If two children are four years old, but one has a spoon silhouette shape, WH and W will differ. Hence, B, W, H, CB, A, SH, WH and W play essential roles in dressmaking, whether they are *princess* dresses, *polo* dresses, *maxi* dresses or other types. As shown in Figure 5-bottom, a basic dress in the standard silhouette shape is fitted (Figure 5-a); however, it is not appropriate, strengthened or puffed up/out for other silhouette shapes, which show two red spots and ten yellow spots (Figure 5-b, 5-c and 5-d). For example, children with rectangle body types will not find this garment convenient as their bodies are boxy silhouettes, and they cannot move their arms quickly (Figure 5-c).

Table 1. Children's size chart with clothing key dimensions in the measurement

sizes	**2**			**3**			**4**			**5**			**6**			**7**			**8**		
height (cm)	*84-92*			*92-99*			*99-107*			*107-114*			*114-122*			*122-127*			*127-135*		
weight (kg)	*13.5-14*			*14-16*			*16-18.5*			*18.5-21*			*21-23*			*23-26*			*26-30*		
measurements	skirt	trouser	top/dress	skirt	trouser	top/dress	skirt	trouser	top/dress	skirt	trouser	top/dress	skirt	trouser	top/dress	skirt	trouser	top/dress	skirt	trouser	top/dress
dress length	26.5		92	28.5		98	30.5		104	32.5		110	34.5		116	37.5		122	40.5		128
chest/bust (B)			**54 N**			**55 N**			**56 N**			**57 N**			**58 N**			**61 N**			**62 N**
waist (W)	**51 N**	**51 N**	**51 N**	**52 N**	**52 N**	**52 N**	**53 N**	**53 N**	**53 N**	**54 N**	**54 N**	**54 N**	**55 N**	**55 N**	**55 N**	**56.5 N**	**56.5 N**	**56.5 N**	**58 N**	**58 N**	**58 N**
hip (H)	**55 N**	**55 N**	**55 N**	**57 N**	**57 N**	**57 N**	**59 N**	**59 N**	**59 N**	**61 N**	**61 N**	**61 N**	**63 N**	**63 N**	**63 N**	**66 N**	**66 N**	**66 N**	**69 N**	**69 N**	**69 N**
neck	11			11.3			11.5			11.7			12			12.2			12.5		
armhole height	13.5			14.1			14.7			15.3			15.9			16.3			16.7		
arm circumference	28			29			30			31			32			33			34		
waist to hip (WH)	**10.7 N**	**10.7 N**	**10.7 N**	**11.5 N**	**11.5 N**	**11.5 N**	**12 N**	**12 N**	**12 N**	**12.8 N**	**12.8 N**	**12.8 N**	**13.5 N**	**13.5 N**	**13.5 N**	**14 N**	**14 N**	**14 N**	**15 N**	**15 N**	**15 N**
centre back (CB)	24.5	24.5	**24.5 N**	25.7	25.7	**25.7 N**	26.9	26.9	**26.9 N**	28.1	28.1	**28.1 N**	29.3	29.3	**29.3 N**	30.7	30.7	**30.7 N**	32.1	32.1	**32.1 N**
across back	10.5			10.7			10.9			11.1			11.3			11.8			12.3		
armhole width	6			6.1			6.2			6.3			6.4			6.7			7		
across chest	10.5			10.7			10.9			11.1			11.3			12			12.7		
shoulder length (SH)			**7.4 N**			**7.7 N**			**8 N**			**8.3 N**			**8.6 N**			**8.9 N**			**9.2 N**
sleeve length (S)			30.6			32.9			35.2			37.5			39.8			42.3			44.8
hand entry			11.8			12.1			12.4			12.7			13			13.3			13.6
crotch length (CL)	18	**18 N**		18.5	**18.5 N**		19	**19 N**		19.5	**19.5 N**		20	**20 N**		20.7	**20.7 N**		21.4	**21.4 N**	
pant length	53			57.4			61.8			66.2			70.6			75.3			80		
inside leg	35			38.9			42.8			46.7			50.6			54.6			58.6		
foot entry	19.6			19.9			20.2			20.5			20.8			21.1			21.4		

***N: measures are variable between 0 to 2 cm that will be changed based on the children's body size and silhouette shape.

Moreover, children with a spoon and oval silhouette shapes (Figure 5-c and 5-d) may experience discomfort in the waist and hip region; the garment is too tight, and children cannot wear it or move quickly unless the stretchy fabric has been chosen.

As shown in Table 1, the original measurements are extracted from Müller & Sohn system; after experiment and simulation, results showed that some measures need to be changed based on the body size, silhouette shape, and garment's key dimensions. Hence, the authors developed the updated children's size chart with measurement variables focusing on garment type and key dimensions. Table 1 shows that some key dimensions play critical roles for each garment, while these dimensions may be neglected for other garment types. In addition, based on the results of this study in simulation and Fit Map process, some measures are varied between 0 to 2 cm based on the children's body size and silhouette shapes. Hence, the existing children's size chart cannot be employed as a reliable reference without considering garment types and measuring their key dimensions. Furthermore, it was observed that four garments discussed in this study have fit problems for the spoon and oval silhouette shapes. It was noticed that a major difference between the clothing key dimensions in hip and waist parts causes difficulties. Henceforth, a developed chart size considering children's body size, silhouette shape, garment types and garment key dimensions should be used by manufacturers, parents and designers.

5. Conclusion

Nowadays, fitting children's garments is a critical issue due to the lack of standard silhouette shapes among children. Based on the findings of this study, the essential factors that could influence the fitting of children's garments are chest, waist, hip and waist to hip, all of which relate to the silhouette shape. Garments' normal appearance and the pressure visuals for each garment according to the standard, rectangle, spoon and oval silhouette types have been illustrated in Figures 2 to 5. Garment patterns were generally evaluated for each silhouette shape, utilising the chest, waist and hip lines and CLO3D software. The views of the virtual mannequins were analysed for the four silhouette shapes using the fitting map. When the visuals are evaluated for each flat pattern piece, different results were obtained for each silhouette shape. The general silhouette shape evaluations revealed that all the patterns seem suitable only for the standard form; once children's measurements are larger or smaller than the standard, the tension changes. The problem is that some measures are adjusted based on the silhouette shape, which is not fixed. Furthermore, it was observed that all garments had fit problems for the spoon and oval silhouette shapes even in one body size. It was noticed that a major difference between the hip and waist parts causes difficulties. Henceforth, the developed chart size considering children's silhouette shapes and key dimensions of each garment type should be used by manufacturers, parents and designers. Moreover, the results of this study indicate that the standard size chart of pattern-making systems is unsuitable for all children's silhouette shapes and body sizes. These fixed measures cannot be trusted as the basis on which to purchase or design clothes unless people know about silhouettes shape and change some measurements based on the garment and fabric types. However, this system seems difficult to perform, so technology should be used to revise the pattern-making techniques for different silhouette shapes. The clothing industry needs some intermediate sizes between the currently available sizes, which is one possible solution. Moreover, developing

platforms like mobile applications for garment patterns, modelling applications and pattern grading according to different silhouettes shape may allow manufacturers to provide fit and satisfaction. It is imperative to find the characteristics of the silhouette shapes of those of different races and in different countries. International silhouette shape comparisons allow the discovery of ways to improve each sizing system. It would also impact the development of international sizing standards, significantly benefiting brands that manufacture products for a variety of global consumers with different sizes and silhouettes.

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