Not All Body Scanning Measurements are Valid: Perspectives from Pattern Practice

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Abstract

To assume all body scanning measurements are valid for apparel product development is wrong. While human measurement forms the basis for product development and body scanning represents a significant development in the collection of human measurements [1], a distinction must be drawn between measurements suitable for product development (pattern cutting) and those required for the creation of sizing systems. The application of body scanning has largely focused on sizing surveys [2], the standards used in developing the technology are tailored toward surveys [3], [4] and subsequently measurements are often not defined in a manner suitable to developing products. This research began with analysis of product development practices and body scanning outputs to determine the suitability of body scanning to support existing methods of product development. Six methods of pattern development, established from previous research to represent the variation of approaches [5]–[7] were selected, the measurements required for these methods were compared to measurement outputs from both a Size Stream and [TC]^2 body scanner. Further analysis was made regarding the development of custom measurements for each scan system, to see if extra measurements could be defined to match those required or enhance the data used to drive the draft process. Whilst there are promising developments in automated pattern creation [8], [9], there is little existing theory or clear understanding of pattern to person relationships to enable the full realization and embedding of these systems. As well as understanding the suitability of scan measurements for pattern development, this research also recommends further measurements which may improve the patterns' ability to accord with the individual size, shape and proportion of the wearer. This research shows that there are a range of measurements used for pattern making and these are not all available from existing body scanning systems. Key landmarks and measurements are identified and this research shows how body scanning technology can be developed to support existing and developing methods of pattern development.

Keywords: Accuracy, Reliability, Appropriateness, 3D Body Scanning, Anthropometrics, Garment Construction**:**

1 Introduction

This paper addresses the challenges of matching measurements generated by the Size Stream and [TC]^2 body scanner with those required for creating garment patterns according to many established pattern drafting methods for the women's bodice.

Through this paper we address the suitability of the body scanner measurements to be used to inform the construction of a bodice block pattern. Currently pattern drafting remains a manual task often performed using one of a number of different methods. Analysis of pattern drafting methods has been undertaken to determine ease [7], understand theories incorporated into the process [5], and even to show how approaches can better recognise the individual size, shape, and proportions used in the process [6]. However there have been no studies focused on how body scanning technology directly informs existing methods of pattern drafting. While this study focuses primarily on the bodice draft, the similarity within the different methods means the findings will be applicable to pattern drafting techniques used for other garment types.

The process of body scanning focuses on capturing a 3D body using image capture [10]. In the case of Size Steam and [TC]^2, Prime Sense IR depth sensors are used with images captured used to create a point cloud. This is finally rendered into a mesh of the human body. The mesh is then analysed to find the measurements. As with manual methods, the 3D avatar is first landmarked and then based on these landmarks measurements are extracted from the avatar.

There have been recent advances in the data possible to capture using body scanning [1], [11] and methods documented to generate patterns directly from scan data [12]–[14]. However, the creation of pattern blocks remains something almost exclusively done manually using 1D measurements, as has been the case from the start of the methods. Another factor which needs to be considered is the application of proportional rules during the draft process [1], [6], [15]. This is often used in place of actual measurements that may have historically been difficult to take. But with the increased capabilities of body scanning, these measurements may form part of the data that informs the creation of the pattern block.

There is recognition that measurement produced using body scanning may not always be comparable to those used manually. For example the hip measurement often uses different markers manually than those available for scan analysis. There is also the impact of posture on measurements to consider [16].

1.1 Aims and Objectives

This paper aims to establish how well the measurements required for drafting a women's bodice can be produced from scans captured using a 3D body scanning technology.

This research undertook analysis of measurements required for six different methods for creating a women's bodice block. Measurements were then compared to those produced by the Size Stream software and those possible to extract using the custom measurement creator. Measurements were further compared against the ISO 8559 standard [17] which details the latest set of measurements considered as important clothing production and sizing.

- This paper allows an understanding of the suitability of body scanning to inform current methods of pattern drafting.
- This paper also highlights areas where measurements are required or further consideration of measurement definitions would allow the body scanner to offer more suitable measurement sot support pattern drafting methods.

2 Methodology

This research applied exploratory methods to capture measurements required for constructing a women's bodice pattern and compared these to dimensions available from a current body scanner. Methods were informed by earlier studies into pattern construction [1], [5]–[7] where dimensions had been captured and analysis undertaken of the draft process. However, even existing studies have not given thorough consideration to the measurements and how they might be defined between different measurement instruments.

2.1 Selection of pattern drafting methods

Six methods for drafting the women's bodice were selected for this analysis; these methods broadly show the different approaches to creating the bodice block using flat pattern drafting from mainly direct measurements. Methods were mostly selected from those used in the UK and consideration given to how they represent current approaches to creating a bodice block [18]. While these methods do not show all possible variations, they follow a clear linear process, use most actual body measurements, and are established for use in education and industry.

Table 1. Pattern drafting methods selected

Method	**Draft process selected**	**Overview of method**
Aldrich 2004[19]	Close fitting bodice block (pg 14-15) close waist shaping (pg 27)	This method is used primarily in the UK and is often used as a core book for those learning to draft patterns. The process is a simple number of steps with an accompanying visual outline of the finished pattern.
Armstrong 2010	Basic pattern set (pg 46-49)	This method is primarily used in the US and is often used a core book for those learning to draft patterns. Measurements are all in inches and the process is sequential over a number of pages, in contrast to other methods, the measurements guidance focuses on measurement of a dress form.
Beazley and Bond 2003	Fitted bodice block (pg 33-37)	This method was developed in the UK and is one of the more direct methods of creating a pattern block. Here, measurements and ease are used directly to define the pattern dimensions.
Holman 1997	Fitted bodice block (pg 38-41)	This method is one of the simpler UK techniques for creating a pattern block, with very simple instructions and an image of the final block.
Khalil 1985	Bodice draft for individual (pg 145-160)	This is an Egyptian method, which is easy-to-follow. Providing a number of visual descriptions and following numbered step-by-step instructions the draft is created. It also illustrates the methods of bust dart manipulation and pattern alteration for figure fitting problems.
Thatha 1995	The basic flat bodice block (pg 18-30)	This method, based on the Profili patternmaking method (Italy), was developed and designed to be easy-to-follow by providing clearer layout including many visual descriptions. It has published by educational institutions (i.e. Ministries of higher education) in various Arabic countries for academic purposes.

2.2 Analysis of measurements required for pattern drafting

A systematic analysis was undertaken to determine the different measurements required for each of the six pattern drafting methods. When measurements were defined in the same way they were grouped together and when they were defined differently they were separated out to show this **Error! Reference source not found.**. Comparison was then made to the measurements defined in the latest ISO standard [17] with measurements grouped under a collective heading when possible.

2.3 Comparison of measurements between the methods and the body scanner

Measurement definitions were grouped in MS Excel based on the guidance for their placement and method of taking as defined in each of the pattern construction guides. These measurements were then compared to those available from the list of core measurements in the Size Stream Studio version 5.2.4.1 [20] and [TC]^2 19 software [21].

Further consideration was given to whether a measurement could be defined using the software when they were not present or differed considerably to the measurement required for the pattern draft. A more detailed analysis of important measurements was undertaken to determine why there may be deviation between manual and body scanner methods. From this, recommendations were made about how body scan measurements can be amended or produced to ensure they provide suitable measurements for each pattern drafting method. Some further consideration was given as to extra measurement which may be defined that might use the increased capabilities of body scanning [1], [11] to better inform the creation of the pattern block. An important consideration to this paper is that measurements are expected to be extracted from subjects following a universal and static scanning protocol to ensure compatibility of scanning results [16], [22].

3 Results and Discussion

3.1 Comparing measurement definitions

Analysis of the pattern methods, standards, and body scanner measurements show some measurements required for the pattern drafts are not available within the scanner software. Additionally, in some cases the measurements are not incorporated into the standards (Table 2). There are also clear differences between some of the measurements required for drafting and those provided from the body scanner.

Ald 2004	Arm 2010	B&B 2003	Hol 1997	Kha 1985	Tha 1995	Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Bust	Bust arc	Bust girth	Bust	Bust girth	Bust girth	Bust	Bust girth (5.3.4)	Chest / Bust Circumference (& Fr Arc)	[102a]-FrBustArc
░	Back arc	░	░	░	░		░	Chest / Bust Circumference Bk Arc	[102b]-BkBustArc
Waist	Front waist arc	Waist	Waist	Waist	Waist	Waist	Waist girth (5.3.10)	OPT Waist Circ & Fr Arc	[108a]-FrWaistArc-[4cm]
	Back waist arc						░	OPT Waist Circ Bk Arc	[108b]-BkWaistArc-[4cm]
Hips	Front Hips arc	Hips	Hips	Hips	Hips	Hips	Maximum hip girth (5.3.14)	Hip Circumference & Fr Arc	[143a]-FrHipB-Arc
	Back Hips arc						░	Hip Circumference Bk Arc	[143b]-BkHipB-Arc
Back width	░	░	Cross Back	░	▒	Across Back	Across back width (5.4.4)	▨	▨
░	Across back	Across back	░	Half back width	▒		░	Across Back Tape Measurement	[83]-XBkWidth
Chest	░	░	░	▒	▒	Across Front	░	▨	▨
░	Across chest	░	Cross Chest	▒	▒		░	▨	▨
░	░	Across front	░	▒	▒		Across front width (5.4.7)	Across Chest Arm to Arm Length	[85]-XFrWidth-Horizontal
Shoulder	Shoulder length	Shoulder length	Shoulder length	Shoulder length	Shoulder length	Shoulder Length	Shoulder length (5.4.1)	Shoulder Length Right	[91]-ShoulderLength-R
Neck size	░	Neck girth	Neck	Neck circumference	▒	Neck Base Measurement	Neck base girth (5.3.3)	Neck Circumference	[87]-NeckBaseGirth
░	Back neck	░	░	░	▒		░	▨	▨
▒	CF length	▒	Centre Front Bodice	▒	▒	Centre Front Neck to Waist	Front neck point to waist (5.4.8)	▨	[41.2]-FrNeck-2-WaistLength
Nape to Waist	CB Length	Nape to waist	Centre Back Bodice	Back length	Back length	Centre Back Neck to Waist	Back neck point to waist (5.4.5)	Half Back Center Tape Measure	[40.1]-Back-Neck-2-Waist-Length-Bk
▒	Bust span	Bust prominence width	▒	Bust prominence width	▒	Bust Width	Bust point width (5.2.3)	Bust-to-Bust Length (Custom)	[86]-BustPointWidth
▒	Across shoulder (front)	▒	▒	▒	▒	Centre Front Neck to Shoulder	▒	Front Shoulder Width	▨
▒	Across shoulder (back)	▒	▒	Shoulder width from nape	▒	Centre Back Neck to shoulder	Back shoulder width (5.4.2)	Back Shoulder Width	▨
▒	Dart placement front	▒	▒	▒	▒	Waist Dart placement (front)	▒	▨	▨
▒	Dart placement back	▒	▒	▒	▒	Waist Dart placement (back)	▒	▨	▨
▒	▒	Front length to bust	▒	▒	▒	Centre Back Neck to BP	Back neck point to bust point (5.4.12)	Cervicale to Bust Length	▨
▒	▒	Front waist level	▒	▒	▒	Centre Back Neck to Waist (pass BP)	Back neck point to waist level (5.4.13)	▨	▨
▒	▒	Front neck point to bust point	▒	Bust point length	▒	Side Neck Point to BP	Side neck point to bust point (5.4.10)	Side Neck to Bust Length Right	[51] SideNeck2Bust_Right
▒	▒	Front neck point to waist	▒	Bust length	Bust length	Side Neck Point to waist (pass BP)	Side neck point to waist level (5.4.11)	▨	[56]-SideNk-2-UBust-Waist-R-Fr
▒	Full length (front)	▒	Shoulder to Waist	▒	▒	Side Neck Point to Front Waist	▒	▨	▨
▒	Full length (back)	▒	Back shoulder to waist	Back length	▒	Side Neck Point to Back Waist	▒	▨	▨
▒	Strap	▒	▒	▒	▒	Side Neck Point to Side Seam	▒	▨	▨
Front shoulder to waist	▒	▒	▒	▒	▒	Middle Shoulder to Waist	▒	▨	[65] R Shouldet to Wasit
Armscye Depth	▒	Armhole Depth	Armhole Depth	▒	▒	Armhole Depth	Scye depth length (5.4.6)	Back Neck to Back Chest	[15.3a]-Scye-Depth-[L:wFrArPt-2cm]
▒	shoulder slope (front)	▒	▒	▒	▒	Shoulder Tip to CF Waist	▒	▨	▨
▒	shoulder slope (back)	▒	▒	▒	▒	Shoulder Tip to CB Waist	▒	▨	▨
▒	Bust depth	▒	▒	▒	▒	Shoulder Tip to BP	▒	▨	▨
▒	side length	▒	▒	▒	▒	Side Seam Length	Side waist length (5.4.9)	▨	▨
Waist to hip	░	▒	▒	░	░	Hip Length	▒	▨	▨
░	side hip depth			Hip length	Hip length		Side waist to hip (5.4.21)	▨	[30a]-Waist-to-HipB-R
▒	▒	Width of Armhole	▒	▒	▒	Width of Armhole	Armscye front to back width (5.2.4)	▨	[94]-ArmscyeWidthCaliper-

░	Measurement is incorporated into another measurement or a simlar measurement is taken
▒	Measurement not required within the guidance
▨	Measurement not currently avaiable from scanner

Table 2: Measurements required for pattern blocks and those provided by standards and the Size Stream body scanner.

3.2 Considerations of measurements required for pattern construction methods

It is clear from the analysis of measurements used in pattern construction (i.e. ISO standard [17] and body scanner software) that variation exists in their definition. Crucially, pattern drafting methods do not use consistent measurements between methods and differ in the detail provided for measurements. This has been recognised in other pattern related research [7]. The following section will deal with a sample of measurements from those analysed that represent measurement. Specifically, where direct agreement can be seen between methods of measurement and those where no clear measurement provided. There will be consideration given to the measurement definition and the constraints of the measurement method.

3.2.1 Comparable measurements produced by the body scanners

The following measurements show those where the pattern practice, standard and scanner measurements appear to be in alignment.

Bust circumference/girth: for all six methods the bust girth was collected in a manner comparable to that available from the body scanner. However, Armstrong [23] requires the measurement to be captured as arcs. This relates better to how the measurement is applied in the pattern [1]. This also brings for consideration the difficulties of side seam placement highlighted by earlier research [24], [25]. A further important consideration is the ISO 8559 [17] determines the bust point as the most anterior projection. This is similar to how the body scanner defines it, but different to historic methods which focused on using the nipple as the point to define the bust. This shows consideration of the developments body scanning brings, as the most forward projection is more suitable. Division into arcs (a clear need of pattern production) requires developments in this area for body scanning to make sure the division occurs in a way comparable to measurement application.

Table 3: Bust measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Bust	Bust girth (5.3.4)	Chest / Bust Circumference (& Fr Arc)	[102a]-FrBustArc
		Chest / Bust Circumference Bk Arc	[102b]-BkBustArc

Waist and hip girths: A similar situation occurs with the waist and hips, where accepting the side seam division into arc's that Armstrong requires. Here, the measurements defined manually and those defined by the body scanner can be seen to be comparable. Should this arc division not be captured through measurement, it will be imposed within the draft process [24]. However, careful consideration of the suitability waist location in 3D Body Scanning is required to make sure that measurements are comparable and suitable [26].

Table 4: Waist and Hip measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Waist	Waist girth (5.3.10)	OPT Waist Circ & Fr Arc	[108a]-FrWaistArc-[4cm]
		OPT Waist Circ Bk Arc	[108b]-BkWaistArc-[4cm]
Hips	Maximum hip girth (5.3.14)	Hip Circumference & Fr Arc	[143a]-FrHipB-Arc
		Hip Circumference Bk Arc	[143b]-BkHipB-Arc

Back neck point to waist (nape to waist): This is a key measurement which determines the position of the waist relative to the CB neck occurring in the control region [1] of any upper body garment. All sources offer what may be considered a consistent definition of the measurement, though naming convention differ.

Table 5: Back neck to Waist measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Centre Back Neck to Waist	Back neck point to waist (5.4.5)	Half Back Center Tape Measure	[40.1]-Back-Neck-2-Waist-Length-Bk

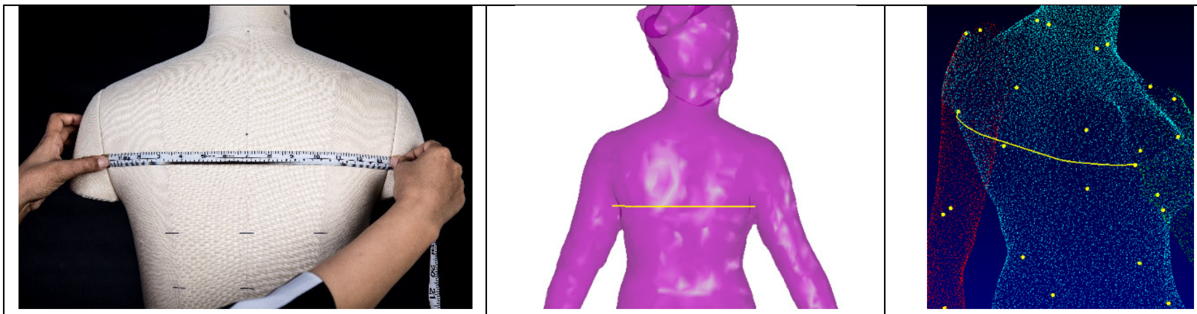
3.2.2 Measurement which differ between manual (pattern) and body scanner methods

The following measurements show those where there is variation between the pattern practice and those returned from body scanning.

Across Back: This measurement is required by five of the six methods. However two methods define the measurement similar to ISO 8559 [17], while three define a measurement more similar to that from Size Stream or [TC]^2. The across back tape measurement available within Size Stream is lower on the body than the manual measurements. But this equates well to a measurement taken typically halfway through the armhole depth. This captures the curves across the back to define the width required of the pattern between the armholes and to allow ease to be placed here. This shows though the definitions are not directly comparable in height, the current resultant measurement can be used to inform the pattern methods.

Table 6: Across Back measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Across Back	Across back width (5.4.4)	▨	▨
	░	Across Back Tape Measurement	[83]-XBkWidth



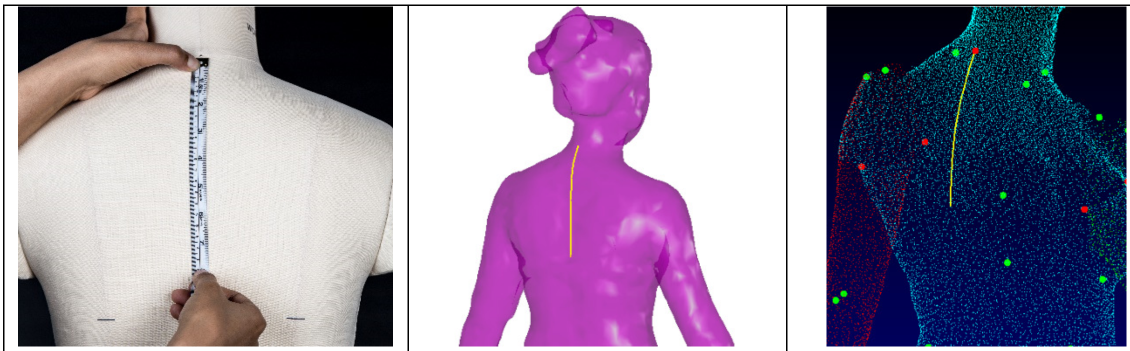
Across Back Required for the Pattern | SS Across Back Measurement | TC 2 Across Back

Figure 1. Across Back measurement images

Armhole/Scye Depth: This measurement which follows the contour of the back down to the level of the lowest point of the armpit can be difficult to take manually; often methods will suggest the use of a set amount. However the body scanner can take suitable measurements. The Size Stream measurement (most suitable) is the measurement to the chest level. However with the [TC]^2 scanner a custom contour can be created that ends at the level of the lowest armpit point. This measurement is one that the scanner can offer more easily than manual methods allow and can directly contribute to improving the fit of the bodice by using actual measurements. This is important as derived measurements can create considerable error [15].

Table 7. Armhole Depth measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Armhole Depth	Scye depth length (5.4.6)	Back Neck to Back Chest	[15.3a]-Scye-Depth-[L:wFrArPt-2cm]



Armhole/Scye Depth | Back Neck to Back Chest | [15.3a]-Scye-Depth-[LwFRArPt-2cm]

Figure 2. Armhole depth measurement images

Shoulder length right: This measurement appears to be uniform amongst all definitions. However careful consideration shows the body scanner places the side neck point more centrally within the neck region on scans from both the Size Stream and $[TC]^2$ scanners. The position which is traditionally defined is where the trapezius and neck column intersect, a soft tissue feature that would be hard to detect from surface geometry alone.

Table 8. Shoulder length measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Shoulder Length	Shoulder length (5.4.1)	Shoulder Length Right	[91]-ShoulderLength-R

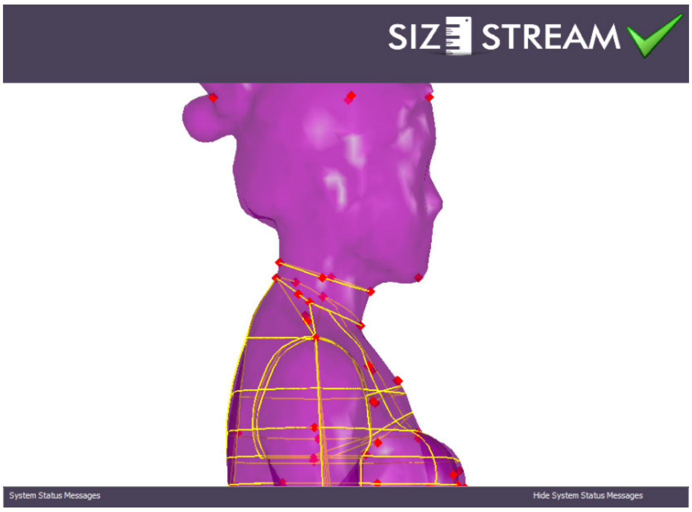


Figure 3. Shoulder length on the Size Stream scanner

Traditionally the shoulder line goes from the middle of the shoulder to a point on the neck that creates and unequal division between the back and front. Typical of many pattern drafting methods, the back neck depth is between 1.5 and 2cm deep. However the front neck is usually defined as a fraction roughly 1/5th of the overall neck circumference. It is clear that applying the shoulder measurement might not mislead this pattern dimension, but for other measurements related to the side neck point, this might introduce error.

Across Front: The Across Front measurement has considerable variation within the pattern drafting methods. However the measurements provided by the body scanners can be seen to equate to some of them. The scanners selected do not offer a measurement which is always defined in the same way as the measurements required in the different in the drafting methods. This is demonstrated in Table 9. The lack of armpit landmarks at the front and back (similar to axilla folds used in manual methods) means the Size Stream scanner may not have the points required to define a measurement similar to traditional methods.

Table 9. Across front measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Across Front	░	▨	▨
	░	▨	▨
	Across front width (5.4.7)	Across Chest Arm to Arm Length	[85]-XFrWidth-Horizontal

Bust Width: This measurement provides difficulties due to the means to locate the bust point, as referenced manual methods would traditionally use the nipple. However, the greatest forward projection would be most suitable as used in the scanner. Though the Size Stream scanner measurement had to be modified as the landmarks used were too far apart to be comparable to those required. In the same way the [TC]^2 scanner did not always determine landmarks which were centrally placed allowing a measurement which would be similar to that gained in manual measurement.

Table 10. Bust width measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Bust Width	Bust point width (5.2.3)	Bust-to-Bust Length (Custom)	[86]-BustPointWidth

3.2.3 *Measurements with no match*

The following measurements cannot be determined from the body scanners.

Side Neck point to back waist: Mapping this contour helps to understand the waist in relation to the side neck point, neither scanner takes a comparable measurement. It may be difficult to extract this measurement, but exclusion from the standard it would suggest low importance. However, without the measurement the scanner cannot easily inform the pattern construction process.

Table 11. Side neck to back waist measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Side Neck Point to Back Waist	▒	▨	▨

Shoulder Tip to CF Waist: This measurement which originates at the end of the shoulder is used within the Armstrong draft method to set the position of the shoulder point. Without it being present the draft would need to be modified to locate this point. Currently neither of the scan systems extract this measurement and it does not feature within the standards.

Table 12. Shoulder tip to CF waist measurements

Measurement Name	ISO 8559-1:2017 Measurement	Size Stream Measurement	[Tc]2 Measurement
Shoulder Tip to CF Waist	▒	▨	▨

4 Conclusions

This paper set out to addresses the challenges of matching measurements generated by 3D Body Scanners with those required for creating garment patterns. Due to differences in the measurement instruments between body scanning and manual methods it is not always possible to replicate each measurement required by the different pattern drafting methods. However, some measurements can be considered to be directly comparable, or at least defined in a way that allows them to be considered as comparable. In some cases measurements required for the draft cannot be defined easily within the software and in limited cases it cannot be defined at all.

The main contribution of this paper is in positioning the importance of measurements required for pattern construction be defined as outputs within body scanner systems, this would enable the measurements to be directly applied by current pattern practitioners.

This paper raises the issues of landmarking considerations as the points defining measurement placement. There is a difference between manual methods which use the geography of the body (often referencing skeletal landmarks) and body scanning, which is reliant upon the geometry of the surface and must infer landmarks from this alone. While some studies pre landmark (CAESAR for instance) this is hugely prohibitive with body scanning, requires modesty considerations and is incredibly time consuming.

Advances in landmaking definitions may allow some of the possible inaccuracies to be overcome, allowing comparable landmark and measurement definitions between manual and scanner methods. This paper shows that body scanning may offer a means to better inform patter drafting methods. However, consideration needs to be given to the purpose/application for the measurement in creating clothing patterns, and developing landmarking/measurements informed by this.

Efforts have been made to automate the process of pattern making. However these processes and the existing methods of pattern construction seem not have been informed the measurement definitions available within the body scanning systems. There is a clear need for body scanners to supply at a minimum all measurements used within current methods of pattern creation. This would allow for scanning to be directly applied within existing methods and offer a foundation for improving the practices. This can be achieved by incorporating more measurements and looking to automate pattern construction in a more informed way. However, the reliability of 3D Body Scanning data needs to be factored into any such developments to make sure that automatically produced pattern blocks are at least of as high a precision as those made through manual methods [27].

The implications for industry are having scan data which relates more directly to the different block drafting methods used to create patterns, this increases their abiloity to create blocks from scan data.

The limitations of this research are in the current theory that support pattern drafting and the understanding of human measurement from scanning and for pattern drafting.

Future research shall focus on the direct application of 3D Body Scanning to automatically draft pattern blocks from scan data. Additionally, this research shall determine how scan data can provide size and fit recommendations for Virtual Fit platforms; as discussed within these proceedings [28].

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