Technology Discovery to Improve the Design Process for Seamless Knitted Sports Bras

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Background. Previous research found that the design process in the knitwear industry is inefficient, caused by the growing skill gap and miscommunications between designers and knitting technicians (Moore & Smith, 2020). Unlike the cut-and-sew knits, where the three-dimensional shaping of a garment is achieved by assembling flat, two-dimensional fabric pieces, seamless or circular knitting involves creating a garment by designing a three-dimensional fabric (McCann et al., 2016). Both designers and knitting technicians, use software that requires a two-dimensional design development, followed by time consuming trial-and-error prototyping and fit sessions (Pitimaneeyakul et al., 2004; Taylor & Townsend, 2014). Several design software, such as *3D Suite* (OptiTex), *Vstitcher*^{TM} (Browzwear), and *Clo3D* (CLO Virtual Fashion Inc.) are currently used by designers to visualize garments and fit on avatars for many types of cut-and-sew designs, but a gap was found on the use of any of such software when designing seamless garments knitted on circular machines (Lee & Park, 2017; Yan et al., 2017).

The purpose of this study was to explore if *Clo3D* software can help the designers in visualizing, developing, and communicating design details of a seamless knitted garment. Sports bras are some of the most complex garments that have been particularly relying on circular knitting manufacturing to incorporate compression and shaped support of the breasts, as well as fabric comfort (Lau & Yu, 2016). Therefore, the focus of this study was on the applicability of *Clo3D* to sports bra design, and two research questions guided the inquiry: (1) what design features are currently used to create a seamless sports bra, and (2) how Clo3D technology can help the design process of such a bra.

Method. A content analysis of online commercial seamless sports bra offerings was performed, and 80 bras from 40 different brands were selected and grouped by three breast support (impact) categories (high, medium, and low). Product information was collected from each brand's website and organized into a Microsoft Excel spreadsheet. The data was categorized based on 15 criteria (brand, price, support level, size, fiber content, percentage of spandex, special function, straps, closures, sweat wicking properties, compression, breast encapsulation, adjustability, ventilation, and customer reviews). Basic descriptive analysis was made using the 'sort and filter' function of Microsoft Excel software, and key design criteria directly related to breast support was determined. Based on these criteria, an elimination process was performed to find which bra is the most complex in design in its category and representative of seamless knitting technology capabilities. After inspection of the physical samples for the final three bras, one was randomly picked to serve for the second stage of the research.

To explore the design process of such a seamless knitted sports bra using *Clo3D* software, a reverse engineering process was used (Šafka et al., 2014). The sample bra of the selected design from the first part of this study was size Medium, to fit the lead researcher and help with further design investigation. After creating flat sketches, measuring the bra, and recording all the specs, a construction and knit stitch pattern analysis was made. Seamless sports bras are knitted in double layers, folded at the bottom of the underbust band, and often the inside layer knit patterns are different from the patterns of the outside layer (Gorea et al., 2021). The flat sketches were used to map out the different areas of the bra with knitted shaping (such as between the breasts on inside layer) or just different knit stitches (Figure 1a). The knit patterns were approximated to standard fabrics available in *Clo3D* database, such as: knit cotton/rayon jersey, knit pique jersey, rib 1x1, knit ponte jersey (Figure 1b).

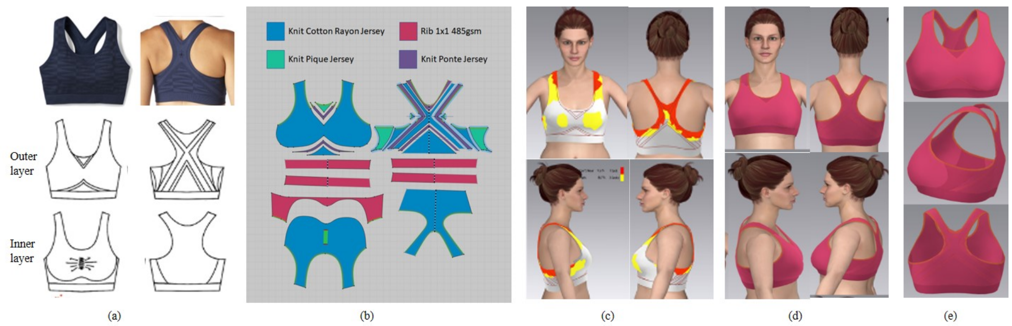

Figure 1. (a) Reverse engineering process of the selected bra design, (b) the identified various knit stich panels, (c) assembled bra pressure mapping in *Clo3D,* (d) final bra fit on customized avatar, and (d) final 3D visualization of the bra design.

An avatar was created to reflect the body measurements of the lead researcher, for the purpose of further assembling and simulating the bra fit. *Clo3D* standard petite curvy size 4 model was adjusted to height of 56”, and circumferences for underbust of 28”, bust 36”, waist 28”, and hip 36”. The bra was digitally assembled and the two layers stitched together by applying a shoulder seam and a 6mm elastic seam tape around all edges. By trial and error, the size of each piece was adjusted based on guidance from the *Clo3D* pressure map combined with lead researcher’s feedback on the perceived fit pressure of the actual bra sample on her body (Figure 1c).

Results and Discussion. The results highlighted that the most supportive seamless knitted sports bras have the following characteristics: higher than 10% spandex in the fiber content, racerback straps, and a mix of knit stich design features offering compression, encapsulation, and ventilation. Some high impact bras are less complex in design than some medium or low impact bras. The bra that was chosen was Smartwool’s Merino Seamless Racerback Bra, medium impact, 15% spandex, encapsulation on inner layer, shown in Figure 1a (Smartwool, 2021).

Clo 3D software accurately captured the visual fit of the sampled bra, but the use of physical perceived pressure on the body along with *Clo3D* pressure map shall be further validated by a quantitative physical pressure measurement (Figure 1d) (Liu et al., 2021). The tubular construction of the knitted bra had to be translated into multiple fabric panels with different knit structures that are not standard in *Clo3D* fabric database. Therefore, the simulation helped visualize the garment on a specific body, also showing the inside layer of the garment, which is helpful for a designer and consumer (Figure 1e). Some of the individual stitch panels were modified to achieve digital like physical fit, therefore the digital bra construction is not accurate to the physical product. Further studies of exactly how much the panels had to be changed and how this information will benefit a seamless knitting technician could lead to significant knowledge and improvement of current seamless knitting design process.

Conclusion. The use of *Clo3D* software can help reduce trial and error sampling during the design and prototyping process of a seamless sports bra, facilitating design of customized garments, and providing a visualization tool enhancing the customer shopping experience. Future studies should be made using various sizes of seamless sports bras and customizing the *Clo3D* fabric library for the specifics of seamless knitted fabrics. Similar investigations using alternative software shall also be pursued and compared. Overall, this research contributes to the body of knowledge on improving seamless knitting design process and showcases an educational project for fashion design students engaged in technology discovery with *Clo3D* software.

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