Seamless Knitted Sports Bra Design: A Responsive System Design Exploration

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Background. The transition of sports bras' uses, from an active lifestyle to resting activities, requires adaptable comfort properties of the design (Quinn, 2010). In the current age of technological revolution, the sports bra industry is still not offering an adaptable and responsive sports bra, which supports the body during high impact sports while feeling soft and comfortable during rest (Hansman, 2017). Moreover, the current commercial sports bras are made using all synthetic yarns and using garment dyeing processes that are not ecological sustainable (McCann, 2005).Thus, the two-fold purpose of this study was to: (a) analyze the materials and processes used in the product development stages of seamless sports bras, and (b) propose a biomimetic design solution for a seamless sports bra that offers responsive breast support during running versus resting activities.

Literature review. A relatively recent survey found that 91% of women say they wear active apparel for purposes other than exercise, and 47% of women say they are likely to dress in activewear all weekend (Cotton Incorporated's Lifestyle Monitor, 2015, para. 4). Women now prefer to wear a sports bra instead of a regular bra (Bowles, 2012). However, the geometrical complexity of women breasts makes designing bras with effective breast support and creating accurate bra sizing very difficult. Zhou et al. (2012) found that various breast biomechanics studies have generated inconsistent findings. Seamless knitting technology is the existing manufacturing choice for compression supportive sports bras (Semnani, 2011). The interface between the knitwear designers and the knit technicians is critical to the success of new sample development (Choi & Powell, 2005). There is a very generous literature studying properties of knitted fabrics made of various fibers and yarns capable of absorbing moisture, as this feature affects their use in activewear (Tiwari et al., 2013). Both cellulose and protein natural fibers have dynamic moisture absorption properties (Stamboulis et al., 2000). Scott (2015) found that the dimensional change at a local scale within individual fibers is amplified throughout a knitted structure. Looking into the future, it is beneficial to seek sustainable manufacturing practices, using natural fibers, if they can provide comparable end-products to the ones made of synthetic fibers (Skomra, 2006). A literature gap was found regarding studies of sports bras that have adaptive, responsive properties. The very few examples of responsive sports bras commercially available involve e-textiles in order to monitor biometrics. Although there are many studies researching fiber, yarn, and knitted fabrics properties, a gap was found in literature exploring how all the materials function in relation to each other, as a hierarchical system design. The use of new technologies to evaluate functional features of sports bras has generated vast amounts of data, with 3D Body Scanning and motion capture cameras being the most used tools. However,

translating the body scanning data into manufacturing specifications is done via trial and error, with no established methodology (Heinsohn, 2005).

Methods and Results. An in-depth interview with an experienced Santoni knitting technician provided data for mapping out the product development process of seamless sports bras. The 45 video and audio recordings that were collected were open coded and resulted in 650 different codes. The analysis of the relationships highlighted a tri-dimensional Business Model for Seamless Knitted Apparel. Separate frameworks were created for Product Development and the Tech Pack Model, to map out the complexities of the processes and identify innovation opportunities.

Furthermore, a biomimetic system framework was used to identify responsive interactions within wool/recycled Nylon yarns and various combinations of rib, tuck and mesh knitting stitches, when actuated by moisture. Twenty patterns were knitted in two different yarns, and physical measurements were performed on all swatches. Although the textile science literature shows that natural fibers swell as they absorb moisture, and this increase in fiber physical properties is enhanced by the knitted structures, this study found that knit fabric thickness decreased when the knitted swatches were actuated by moisture. Relaxation of wool fibers when absorbing moisture is therefore confirmed, as suggested by Őner & Okur (2013). Moreover, during the wetting process of the fabric swatches, mechanical change was observed, as per Scott (2015).

Combining results from testing of the knit swatches and product development mapping process, 15 sports bras were made and wear- tested using 3D body scanning in 14 different conditions (no bra, dry, after run, after rest 30 minutes)(Gorea & Baytar, 2016). Questionnaires asked subjects to evaluate perceived comfort and breast support during the testing stages. Results revealed that the new responsive design offers statistically significant compression in the dry condition. The bra became significantly less compressive after run. This result was however contradicted by the perceived breast support evaluated in the questionnaire, which showed that there was no significant difference in perceived breast support between the two conditions. After rest and partial drying, the compression returned to close to dry conditions. Overall, the analysis of the 3D body scanning results and questionnaire responses revealed that responsiveness of the new sports bra design was achieved but varied by subject, so improvements in the design should be pursued.

Significance and future research. The proposed systematic approach to the sports bra design, integrating together all processes and materials of a hierarchy serving the same function, that of offering responsive breast support, provides a new framing for the design process of a sports bra as a functional design garment. An investigation into alternative knitting technologies and their product development processes, could offer a more complete mapping of the sports bra product development process. The use of wool yarn as a functional material in activewear is in the infancy stages and requires further explorations. Moreover, this study highlighted the importance of combining results from 3D body scanning with data from questionnaires, to better evaluate perceived garment compression. Advances in the science that translates body metrics into material manufacturing will lead to improvements in the performance of the sports bras as

functional apparel, supporting the increase in sports participation and healthy lifestyle for women of all shapes and sizes.

References

Bowles, K. A., Steele, J. R., & Munro, B. J. (2012). Features of sports bras that deter their use by Australian women. *Journal of Science and Medicine in Sport*, *15*(3), 95-200.

Choi, W., & Powell, N. B. (2005). Three dimensional seamless garment knitting on V-bed flat knitting machines. *Journal of Textile and Apparel, Technology and Management*, *4*(3), 1-33.

Cotton Incorporated's Lifestyle Monitor (2015, February 12). *A Matter of Comfort.* Retrieved from http://lifestylemonitor.cottoninc.com/a-matter-of-comfort.

Gorea, A., & Baytar, F. (2016). Towards Developing a Method for Identifying Static Compression Levels of Seamless Sports Bras Using 3D Body Scanning. In *Proceeding to 7th International Conference on 3D Body Scanning Technologies*, Lugano, Switzerland.

Heinsohn, F. (2005). TRIZ applied in product development project prioritization. *Theses*and Dissertations. Paper 886.

Hansman, H. (2017, March 1). *The Sorry State of the Sports Bra Industry.* Retrieved from https://www.outsideonline.com/2157141/lack-support.

McCann, J. (2005). Material requirements for the design of performance sportswear. *Shishoo. R.(Ed). Textiles in Sport*, 44-70.

Öner, E., & Okur, A. (2013). The effect of different knitted fabrics' structures on the moisture transport properties. *Journal of the Textile Institute*, *104*(11), 1164-1177.

Scott, J. (March, 2015) Mutate: The Evolution of a Responsive Knit Design System. *In Proceedings of the 2nd Biennial Research Through Design Conference, 25-27.*

Semnani, D. (2011). Advances in circular knitting. In Advances in knitting technology, Au, K.F. (ed.). London: Woodhead Publishing.

Skomra, E. (2006). A comparative study of athletic apparel made from cotton. *Masters Theses and Doctoral Dissertations*, 21.

Stamboulis, A., Baillie, C. A., Garkhail, S. K., Van Melick, H. G. H., & Peijs, T. (2000). Environmental durability of flax fibres and their composites based on polypropylene matrix. *Applied Composite Materials*, *7*(5-6), 273-294.

Tiwari, S. K., Fei, P. T. C., & McLaren, J. D. (2013). A pilot study: Evaluating the influence of knitting patterns and densities on fabric properties for sports applications. *Procedia Engineering*, *60*, 373-377.

Quinn, B. (2010). *Activewear*. In V. Steele (Ed.). The Berg Companion to Fashion. Oxford: Bloomsbury Academic. Retrieved from https://www.bloomsburyfashioncentral.com/products/berg-fashion -library/encyclopedia/the-berg-companion-to-fashion/activewear.

Zhou, J., Yu, W., & Ng, S. P. (2012). Studies of three-dimensional trajectories of breast movement for better bra design. *Textile Research Journal*, *82*(3), 242-254.