# Half-scale Body Forms in Active Poses for Design Development: Use of Pressure Data for Bicycle Clothing Design

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## Abstract

Considering the importance of 3D body shapes and designing with 3D bodies directly, new tools of fit evaluation and garment design are investigated. In this research, we explore half scale body forms in the cycling pose as a tool for pressure measurement for tight fitting bicycle wear. Comparison of pressure values were conducted, which were obtained from participants and their half scale forms produced by 3D body scanning in the active pose. As a subsequent research phase, production and material alternatives for half scale body forms were investigated. Even though the correlation between the pressure values from half scale forms and human participants is not strong enough to replace participant testing, tests with alternative forms indicated reliability in pressure measuring for each of the suggested half scale forms in this research.

**Keywords:** 3D body scanning, half scale body/dress forms, active body pose, bicycle clothing, pressure measurement

## 1. Introduction

The dimensions of the human body vary during motion; therefore, accommodating body dimensions in active poses is critical in designing clothing, particularly for activewear, which should move in tune with the body [1]. For tight fitting garments, design of activewear should ensure the appropriate clothing pressure [2] and pressure values provide data regarding a garment's comfort and function. In this research, we explore half scale body forms in the cycling pose as a tool for pressure measurement for tight fitting bicycle wear. This study does not focus on testing a specific pressure sensor for accuracy or sensitivity, or to measure/quantify the pressure applied with the test garments. Instead, this research investigates the use of mannequins/body forms in the active pose in comparison to testing on the human body, with the ultimate purpose of improved garment design and fit testing.

Miniature mannequins and scaled down dress forms conserve space and resources, and thus have long been used in academic settings as an aid to teaching patternmaking and also for research activities. They are also used in industry, mainly for customization and presentation purposes.

As a further contribution to scaling down the mannequins, the introduction of 3D full body scanning has made it possible to create dress forms from digital files of actual 3D body shapes, and scale these to a precise half scale. Patterns developed on these forms can be digitized for easy scaling to provide a pattern ready for final fit testing on a fit model. Ashdown, *et al.* (2014) developed custom half scale forms using scans of individuals in order to investigate various methods of in-house half scale dress form development [3]. Another research direction within this concept has been the use of half scale dress forms in the active pose, and their contribution to activewear design and fit testing has been investigated with the case of cycling and golf wear by Vuruskan and Ashdown [4]-[6].

Scaled mannequins are also used in pressure measurement, mainly for research purposes, to overcome current limitations in pressure measurement on human body. In order to obtain pressure data from the human body, Fan and Chan (2005) highlight the limitations such as (1) issues in accuracy and reproducibility caused by body movement, (2) processes that are time consuming, expensive and demanding with human participants, and (3) possible changes on the human body and the test garments over time; consequently, they suggest that a mannequin dummy could be a valuable alternative for pressure tests. They have used standard mannequins to simulate the body, and from the clothing pressure obtained from these, are able to estimate the clothing pressure on the human body [7].

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Special mannequins were preferred to acquire values in a range of research such as the pressure studies reported by Doan, *et.al.* (2003) and by Jeong, Hong, and Kim (2006) [8]-[9]. In addition, augmented mannequins are suggested as a controlled testing environment by Compton, *et al* (2018), extending the paradigm of mannequin-based pressure evaluations [10]. They suggest that pressure measuring on a mannequin could be preferable due to the potential for precise and repeatable measurements. However, they highlight fabrication cost limitations of mannequin measuring, due to the need to produce multiple shapes, problems that are addressed with the development of half scale mannequins. The Compton research also cited differences in mechanical properties compared with the human body, which were also explored in this research project.

In this research, we focus on an investigation with dress forms in the active pose, in which 3D body scanning is used to produce exact half scale copies of the human body. Pressure values were obtained from the half scale forms of participants in different sizes, by using pressure sensors. Evaluations were conducted by comparing these pressure values with human participants, and then production options for active half scale dress forms that are appropriate for pressure measurement were explored.

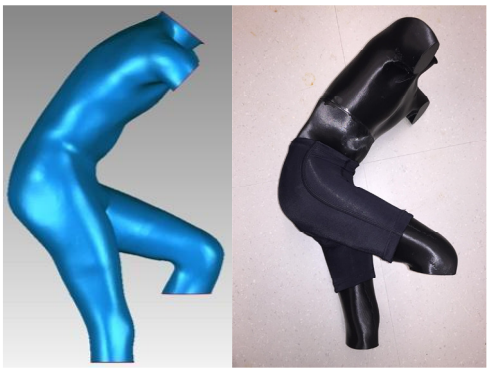
## 2. Methods and Procedures

For the research project, twenty-five cyclists were recruited. Using Vitus Smart XXL 3D Body Scanner, participants were scanned in both standing and cycling positions. Four participants were chosen to represent the sizes S, M, L and XL for further pressure measurement tests [4]. Using the 3D body scan data of participants representing size S and L, cycling-posed half scale body forms were produced for pressure measurements by 3D printing (Figure 1). Using the same pressure sensors and exact half scale reproductions of the bicycle shorts and bibshorts, pressure measurement tests were conducted on participants in the active pose and on their half scale body forms using identical sensor locations (Figure 2).

The follow up phase involved a comparison of pressure data by measuring on three different types of forms to understand the effect of different production techniques and materials.

Two half scale forms were prepared by using different materials in 3D printing, and one half scale form was prepared by using the technique of stacking foam layers together[1]. PLA and TPU were the two materials used for 3D printing for investigating material effect on pressure. Printing with PLA resulted in a harder plastic mannequin, while the testing of various densities of flexible TPU enabled finding the softness of form that corresponded most closely to the human body.

Surface contact pressures were measured with these half scale forms in the cycling pose. Similar sensor locations, and two different bicycle clothing (shorts and bibshorts) were used for these tests. Figure 2 shows images of the pressure sensors on one of the participants and on the half scale forms. For each material, and for each design, 6 repeats were conducted at different times.



(a) (b)

*Fig 1.*

*(a) Avatar obtained by augmenting 3D body scan data from participants in the cycling pose*
*(b) 3D printed half scale dress forms with the bicycle shorts*

[1] Further information regarding the preparation of half scale forms is given in Vuruskan and Ashdown (2017) [4]

(a) (b) (c)

*Fig.2.*
*(a) Measuring pressure on participants*
*(b) Measuring pressure on 3D printed half scale forms*
*(c) Measuring pressure on stacked foam half scale forms*

## 3. Results and Discussion

### 3.1. Comparisons between the pressure values from human participants and their half scale forms

The pressure values obtained from human participants and their half scale body forms were evaluated based on two different sizes, as small and large, and for three different poses, as standing, cycling bent leg and cycling straight leg as seen in Figure 2.

Even though some pressure results from sensors show similar tendencies, it is also noticeable that there are some differences in the results. A clear outcome in the comparisons is that the pressure values from half scale forms are higher than the values from human body. However, it is difficult to identify a pattern of change between two groups of data.

By investigating whether there exists a correlation between the pressure data obtained from these two participants and their half scale forms, results of the Pearson correlation test indicated that there is only a fair degree of relationship (r=0,295, p=0,011) [11] considering the data from both sizes. As seen in Figure 3, an apparent fair degree of correlation is illustrated.

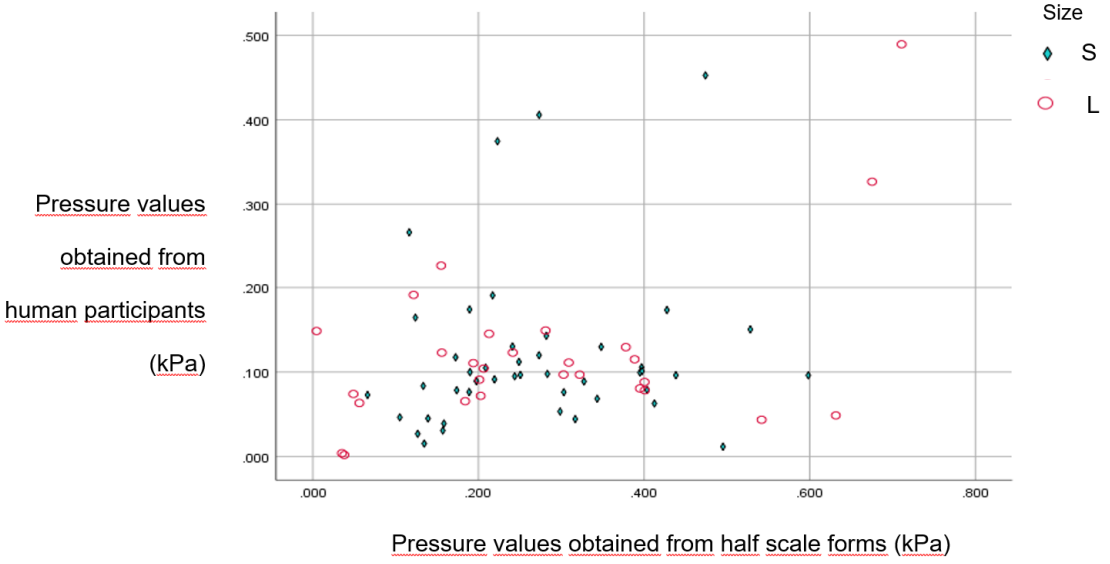



*Fig. 3. Pressure values obtained from human participants (Size S and L) and their half scale forms*

When the sizes are compared individually, it is seen that no correlation exists between the pressure values from the first participant (Size S) and his half scale form (r=0,128, p=0,403), whereas a fair degree of relationship (r=0,478, p=0,010) exists for the data obtained from the second participant (Size L) [11].

By focusing on the cycling pose variations, pressure data obtained from the straight leg and from the bent leg in the extreme cycling position were compared as seen in Figure 2. A deeper analysis considering alternative leg position suggests that the pressure data obtained from the straight leg in the cycling position refers to the most correlation (r=0,459, p=0,012), however, even this correlation is still not strong enough to develop a model between the values of human body and the half scale form.

Applying the same type of pressure measurement technique for measuring two completely different interfaces (surfaces) with different mechanical properties, as the human skin and half scale forms, it is expected that there could be major differences and there would not be a strong correlation. However, the concept of using half scale forms for pressure measurement can be expanded for further purposes, such as identifying negative ease allowances and defining fixed values for tight fitting garments initially before introducing the human factors, which afterwards can be used to estimate the pressure on the body. The methods in this research and these preliminary results could enlighten further research with increased numbers of participants and type of forms as further work. More participants in the size range may introduce new ideas for the relationship between pressure values and size change.

Since pressure differences between participants and mannequins are related to many issues, one of which is the surface dissimilarities, the subsequent investigation inquires the reliability of pressure measurement on active half scale dress forms; and pressure data from various forms produced with different methods were compared with each other.

### 3.2 Comparison of production methods

In previous part, while comparing the pressure data with the human subjects, all of the half scale forms were prepared by 3D printing methods with PLA as hard plastic forms in order to keep this parameter stable. In order to expand the scope of active half scale forms, the consequent analysis included the investigation of the effect of alternative materials and different methods of half scale production on pressure results. Pressure results obtained from six measuring sessions and two different garment types indicated a high level of intraclass correlation [12][2] for all three forms referring to the reliability for pressure measurement with each of the half scale form. ICC results are given in Table 1.

*Table 1. ICC analysis for three different half scale form production techniques.*

| | | | %95 Confidence Interval | |
|---|---|---|---|---|
| | | Intraclass Correlation Coefficient | Lower Bound | Upper Bound |
| FORM 1 (3D printed / hard plastic / PLA filament) | Shorts | 0,987 | 0,967 | 0,997 |
| | Bibshorts | 0,956 | 0,888 | 0,988 |
| FORM 2 (Produced with stacking foam layers) | Shorts | 0,976 | 0,938 | 0,995 |
| | Bibshorts | 0,955 | 0,885 | 0,988 |
| FORM 3 (3D printed / soft plastic / flexible TPU filament) | Shorts | 0,96 | 0,895 | 0,991 |
| | Bibshorts | 0,965 | 0,912 | 0,991 |

There are significant differences between the values from each form, as expected, due to the different physical properties of the material. However, since the repeats with each material indicate a reliable correlation among each group, all three methods of active half scale production tested in this research are suggested as potential materials/ methods for tests with pressure measurement, and consequently garment development.

[2] Koo and Li (2016) claim that based on the 95% confidence interval of the ICC estimate, values greater than 0.90 are indicative of excellent reliability. [12]

In addition to the standing pose, developing dress forms in the active poses might have specific limitations and requirements. In our case with the cycling pose, it was seen that, for the production methods, some adjustments could also be considered in order to improve the practicality of pressure measurement. For instance, specifically for the bicycle shorts and bibshorts, since they have paddings in the crotch, it is very difficult to don the shorts on the forms and they do not fit into the crotch as closely as on the human body. The asymmetrical pose makes it even more difficult to put the shorts on the body and to get a good fit. Printing the straight leg separately and making his legs as attachable parts could provide improvement regarding this. Such pose specific explorations will contribute the improvement of active half scale form production, mostly based on iterative methods and by responding/fulfilling the demands of the sports activity.

## 3. Conclusion

Pressure measuring on half scale dress forms could be preferable for some purposes due to the potential for precise and repeatable measurements for tight fitting garments. The alternative methods of active half scale production, such as the ones compared in this research, will lead the way to create varieties and options for users in terms of cost, surface, shape, size, sports activity, etc. depending on the purpose.

Since accommodating the body in the active poses is critical in garment design, active half scale forms can support product development phases for activewear, where some main poses are particularly important and need to be considered, and/or customized, for enhanced comfort and performance. Pressure values could vary based on human factors and in the case that reliability is provided with the help of half scale dress forms, which are exact replicas of human body, they would be supportive tools to design on the 3D body directly in the desired active pose. The pressure results from three different types of half scale forms in this research indicated a high level of intraclass correlation demonstrating the reliability of pressure measuring for each of the suggested forms.

With the convenience of preparing half scale forms by transforming from real body form with the help of 3D body scanning, forms can be reproduced in selected pose, size and shapes. Use of half scale dress forms in the active pose is introduced as a new concept here and the investigations are conducted with limited resources. These preliminary results should be extended by increasing the number and type of forms as further work.

## References

[1] Ashdown, S., “Improving body movement comfort in apparel,” in Improving Comfort in Clothing, G. Song, Ed. Cambridge: Woodhead Publishing Limited, 2011, pp: 278-298.

[2] Seo, H., Kim, S., Cordier, F., and Hong, K., “Validating a cloth simulator for measuring tight-fit clothing pressure,” *In Proc. Of ACM Symposium on Solid and Physical Modeling*, Beijing, China, June 04 – 06, 2007, pp. 431-437, https://doi.org/10.1145/1236246.1236308

[3] Ashdown, S., Devine, C., Barker, T. Forker Ruoff J., and Cegindir, N. “Development of half-scale forms for the apparel industry,” *in Proc. ITAA Conference*, Charlotte, North Carolina, US. Nov. 11-17, 2014.

[4] Vuruskan, A., and Ashdown, S., “Modeling of half scale human bodies in active body positions for apparel design and testing”, in *International Journal of Clothing Science and Technology*, Vol.29, No.6, 2017, pp.807-821. https://doi.org/10.1108/IJCST-12-2016-0141

[5] Vuruskan, A. and Ashdown, S., “Reimagining design of golf clothing: Addressing the asymmetrical pose”, *In Proc. of 8th 3D Body.Tech Conference & Expo*, Montreal, Quebec, Canada, 11-12 October 2017, pp:113-119, https://doi.org/10.15221/17.113.

[6] Vuruskan, A. and Ashdown, S., “Half Scale Dress Forms from 3D Body Scans in Active Poses”, *In Proc. of International Conference on Human Systems Engineering and Design: Future Trends and Applications*, Munich, Germany, 16-19 September 2019, Vol 1026, Springer, Cham, https://doi.org/10.1007/978-3-030-27928-8_103

[7] Fan, J. and Chan, A.P. “Prediction of girdle’s pressure on human body from the pressure measurement on a dummy”, in *International Journal of Clothing Science and Technology*, Vol. 17 No.1, 2005, pp. 6-12, DOI 10.1108/09556220510577925.

[8] Doan, B., Kwon, Y., Newton, R., Shim, J., Popper, E., Rodgers, R., Bolt, L., Robertson, M., and Kraemer, W., “Evaluation of a lower-body compression garment”, in *Journal of Sports Sciences*, Vol.21, No.8, 2003, pp.601-610, DOI: 10.1080/0264041031000101971

[9] Jeong, Y., Hong, K., and Kim, S-J., “3D pattern construction and its application to tight-fitting garments for comfortable pressure sensation”, in *Fibers and Polymers*, Vol.7, No.2, 2006, pp.195-202.

[10] Compton, C., Berglund, M. E., Dunne, L. E., Chen, J., Brubaker, D., and Bunyard, C. “Development and Characterization of a Mannequin-Based Method for Fit Measurement of Wearable Systems”, *In Proc. of 48th International Conference on Environmental Systems ICES-2018-208*, Albuquerque, New Mexico, US, 8-12 July 2018.

[11] Dawson, B. and Trapp, R.G., *Basic and Clinical Biostatistics*, 4th Ed. McGraw-Hill, 2004, p.48., ISBN:0071414017-1

[12] Koo, T.K., and Li, M.Y., “A guideline of selecting and reporting intraclass correlation coefficients for reliability research” in *Journal of Chiropractic Medicine*, Vol.15, 2016, pp.155-163, https://doi.org/10.1016/j.jcm.2016.02.012