RAE2026

A Dynamic Manikin System for Objective Evaluation of Bra Designs

Prof. Yick Kit-lun

PolyU UoA38

11.2025

Contents

Title: A Dynamic Manikin System for Objective Evaluation of Bra Designs

Descriptor

Funded by two Innovation and Technology Fund (ITF) grants totalling HK$2.8 million (2019–2023), this research addresses critical gaps in sports bra design by developing a dynamic biomechanical testing system that simulates human breast motion during physical activities. To overcome the limitations of traditional static dress forms and subject tests, Prof. Yick and the team engineered a soft-breast manikin that replicates 3D human body movement and soft tissue dynamics during running, cycling and jumping. This manikin enables the precise quantification of sport-specific breast support needs, allowing for customised fit and enhanced comfort in sports bras.

By integrating biomechanics and anthropometry, the project systematically characterises the breast support performance and contact pressure of bras under realistic, dynamic conditions. More than 80 bra designs were rigorously tested, yielding actionable insights into the material properties and structural features critical for reducing breast displacement and discomfort. These findings provide designers and manufacturers with a science-driven framework to translate biomechanical data into practical design improvements and thereby ensure optimal comfort, protection and performance for users.

The project's success is evidenced by three patents, a gold medal at the 2023 Geneva International Exhibition of Inventions, and extensive industry engagement. Collaborations with global brands (e.g. NIKE and GAP Inc.), international activewear manufacturers and a global testing corporation have resulted in licensing agreements and a start-up securing HK$2M for system refinement. The research is also recognised in Top Form Group's 2024 CSR report and was featured in *CHOICE* magazine by the Consumer Council. Research outputs have been published in 9 leading journals and conferences, advancing both biomechanical science and activewear design. Ongoing collaborations are supported by Non-Disclosure Agreements (NDAs), contract research and recently renewed licensing agreements, which underscore the project's significant sustained impact on both academic research and industry practice.

Prof. YICK Kit-lun

Prof. Yick specialises in ergonomic design to improve human well-being, focusing on patient clothing, activewear and footwear. She integrates 3D anthropometry, biomechanical analysis and material science to enhance comfort and functionality, particularly for vulnerable populations. Her research involves developing advanced manikin systems for bra evaluation (MCO1) and applying 4D motion analysis to optimise sports bra fit and support for elite athletes (MCO3), translating biomechanical data into improved movement and power efficiency. She has also established robust methods to predict pressure distribution and combine foot biomechanics and dynamic anthropometry to design custom orthotic insoles for diabetic patients (MCO2).

Prof. Yick's role in research projects is characterised by her ability to define design criteria, propose material innovations and develop prototypes that address needs in sports, rehabilitation and personalised care. She maintains scientific rigor by establishing objective assessment frameworks to evaluate prototype performance. In addition to the government, which provides funding for her projects, her collaborative network includes the Hong Kong Intimate Apparel Industries' Association, Hong Kong Sports Institute, activewear brands, global testing and certification firms, healthcare institutions, NGOs and the Laboratory for Artificial Intelligence in Design under InnoHK. These partnerships reflect her commitment to interdisciplinary collaboration, ensuring that her work contributes to both academic advancement and practical benefits for industry and society.

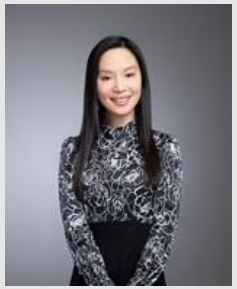
Prof. YICK Kit-lun

Multi-disciplinary Research

Co-Investigators

Prof. Yip Joanne
Professor, PolyU

Materials Scientist & Textiles Technologist



Dr. Ng Sun-pui Zerance
Principal lecturer, HKCC, PolyU

Mechanical Engineer

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Prof. Yip, a materials scientist and textile technologist, leads the selection and characterisation of advanced fabrics and materials to ensure that the manikin system accurately replicates human tissue properties for realistic simulation and reliable testing outcomes.

Dr. Ng, a mechanical engineer, oversees the structural design and mechanical modeling of the manikin, optimising its movement, articulation and response to dynamic forces to ensure realistic performance testing..

Research Questions

Bras are one of the most complex engineered apparel products that have intricate construction details and unique fit requirements to improve body shape. However, owing to the inadequate evaluation methods available, little is known about the influence of bra design features and material properties on fitting, breast motion behaviour and pressure comfort in dynamic situations; thus, most bra designs are based on the experience of individual designers. The research questions for this project are as follows:

1. As compared with the traditional method of bra evaluation, which involves wear trials with human subjects, how should 3D bra shape and fit be objectively assessed?
2. How should the breast support performance of bras, particularly in various dynamic situations, be precisely characterised to provide reliable information for improving bra designs for effective control of breast displacement?
3. Can pressure and wear comfort of bra designs be scientifically quantified and compared?
4. On the basis of breast biomechanics results, what are the key bra design features for stabilising breast motion and wear comfort?

Research Outputs

- **A manikin that includes a rigid human structure with a layer of soft artificial skin and changeable silicone breasts provides adequate breast shape geometry and properties for bra fit evaluation.**
- **By integrating a 6-degree-of-freedom (DOF) robotic automation system, the complex human body motion during various sports activities can be reliably replicated.**
- **Custom-designed body landmarks and an optimised low-cost simple motion track system can effectively measure the 3D motion of the breast and body in *X*, *Y* and *Z* directions.**
- **Despite the discomfort caused by high bra pressure, tight-fitting sports bras with high pressure are associated with breast support, positive sensations of pressure comfort and a sense of security.**
- **Activity intensity, Young's modulus of shoulder strap and bra cup, and underband tension are major bra parameters for effective control of breast displacement during exercises.**

The project has yielded substantial research outputs, including three conference papers at international forums and 6 refereed journal articles in top-tier journals, advancing knowledge of multiplanar breast support, pressure distribution, comfort and fit in sports bras. Three patents have been granted/filed for innovative system designs that allow designers to assess sport-specific support needs and achieve customised fits, demonstrating both academic and practical advancements in ergonomic sports bra design. The project received a gold medal at the 48th International Exhibition of Inventions in Geneva (2023) and secured licensing agreements with an international fashion brand, an activewear innovator and a start-up company. Leading companies, such as NIKE, GAP Inc., Gymshark and MAS Holdings, have invited the team for seminars, sample evaluations and keynote speeches in events such as the NIKE's inaugural Breast Symposium. The project also earned Prof. Yick the 2024 School Knowledge Transfer Award and was featured in the *CHOICE* magazine.

Research Outputs

*The research is supported by local government funding (**HK$2.8M**).*

Category	Contents
Conference Articles	• Sun Y, **Yick KL**, Tang KPM, Yu A, Yip J, Ng SP. (2020). Control performance of different bra designs and materials during physical activity. AATCC Sustainability Innovation and Fashion Technology International Conference (AATCC-SIFTIC 2020). October 15–17, Shanghai, China. • LIU QL, **Yick KL**, Chan KC, Wong ST, Ng SP. (2022). Sports bra pressure: effect on core body temperature and comfort sensation. 13th International Conference on Applied Human Factors and Ergonomics, AHFE 2022, New York, USA, 24–28 July 2022 • Hui KT, Cheah YT, **Yick KL**, Yip J, Ng Z, Ching H. (2024). Approach of evaluating breast motion for sports bra design. AHFE 2024, Nice, France.
Journal Papers	• Lee CW, **Yick KL**, Ng SP, Yip J. (2020). Soft manikin as tool to evaluate bra features and pressure. IJFDTE, 13(2):204-212. • Tang KPM, **Yick KL**, Li PL, Yip J, Or KH, Chau KH. (2020). Effect of contacting surface on the performance of thin-film force and pressure sensors. Sensors, 20(23):6863. • Zhang SC, **Yick KL**, Yip J, YU W, Tang KPM. (2021). An understanding of bra design features to improve bra fit and design for Chinese older women. TRJ. 91(3-4):406-420. • Sun Y, **Yick KL**, Cai Y, Yu W, Chen L, Lau N, Zhang SC. (2021). Finite element analysis on contact pressure and 3D breast deformation for application in women's bras. Fibers and Polymers, 22(10):2910-2921. • Lee CW, **Yick KL**, Ng SP, Yip J. (2021). Analysis of dynamic vertical breast displacement for the design of seamless moulded bras. JTI, 111(10):1470-1480. • Hui KT, Zhang L, **Yick K**, Yip J. (2025). Running-specific breast manikin system for evaluation of breast movement and sports bra performance. JEFF, 20:1-6.
Patents	• 用于胸罩优化设计的人体模型系统, China Patent filed on July 30, 2020. • 用于评估文胸支撑性能的人体模型系统及评估方法, China Patent granted on March 28, 2025. • 乳房运动模拟装置、方法、文胸及乳房假体评估系统, China Patent filed on April 24, 2025.

Research Outputs | 01 Conference Articles

ARFEE - International Symposium on Architecture Research Frontiers and Ecological Environment

E3S Web of Conferences **237**, 04026 (2021)

Control Performance of Different Bra Designs and Materials during Physical Activity

Y Sun, KI Yick, P L Li, M Tang, A Yu, J Yip and S P Ng

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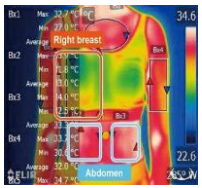
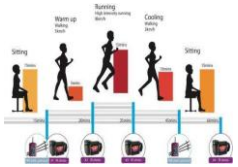
Abstract

Bras give support to the breasts and prevent damage to their different components during daily activities. Previous studies have however merely focused on specific types of bras and/or shoulder straps but failed to provide specific guidelines on bra features and materials that can be used to improve the support different functions of bras. The purpose of this study is to evaluate the breast control performance of various types and designs of bra under the conditions of walking and running. Two younger women and 1 older woman (all with a bra size of 36C/80C) have participated in a wear trial to don a total of 12 different commercial bras with different design features, and a changeable bra in which 12 different variables are examined, including the materials, strap width and type of underwire. The 3D movement of the breasts in the various bra conditions during walking at a speed of 4 km/h and running at 6 km/h is recorded and then compared with the braless condition by using an 11-camera motion capture system. The percentage of change in the nipple displacement in the vertical direction relative to the clavicle displacement is used to quantify and compare the breast control performance of the bras. A significant difference ($p<0.01$) in the ability of the bras to control movement is observed between the group of younger subjects and the mature subject (left breast: 11.49% vs. 35.42%, and right breast: 18% vs. 32.47%, respectively). The control performance of the bras is significantly different ($p<0.01$) during running and walking (left breast: 26.39% vs. 12.54%, and right breast: 30.04% vs. 15.61%, respectively). The correlation analysis showed that a small bra cup volume (length across the bra cup), taller gore, elongation of the bra strap and bra band, and rigid bra cup fabric allow good control of vertical breast displacement.

Sun Y, **Yick KL**, Li PL, Tang M, Yu A, Yip J, Ng SP. (2021). Control performance of different bra designs and materials during physical activity. In E3S Web of Conferences (Vol. 237, p. 04026). EDP Sciences. 3rd International Symposium on Architecture Research Frontiers and Ecological Environment (ARFEE 2020). https://doi.org/10.1051/e3sconf/202123704026





Ergonomics in Design, Vol. 47, 2022, 627–634
https://doi.org/10.54941/ahfe1001991

Sports Bra Pressure: Effect on Core Body Temperature and Comfort Sensation

Qi-Long Liu[1], Kit-Lun Yick[1,2], Kam-Ching Chan[2], Sin-Tung Wong[1], and Sun-Pui Ng[3]

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[3]School of Professional Education and Executive Development, The Hong Kong Polytechnic University, Hong Kong

ABSTRACT

Background: Sports bras are engineer designed to enhance sports performance, which means that they need to provide an excellent fit, and offer adequate support and protection of the breasts to optimize their functionality. To effectively reduce breast motion during different intensity levels of exercise, the materials of sports bras are generally rigid which exert compressive forces onto the soft tissues of the breasts. However, these materials may still restrict air flow and inhibit body heat loss, while the pressure from the bra exerted onto the skin may also increases physiological strain and wear discomfort. This excessively high exerted pressure is known to produce an inhibitory effect on the sweating rate and associated with a significant rise in the axillary and core temperatures. This preliminary study therefore investigates the influence of bra pressure on the upper body temperature and thermal comfort following a short duration of treadmill running.
Objective: The purpose of this study is to investigate the effect of increased bra pressure on thermal response following exercise. The findings provide bra designers with insight into bra pressure and related bra design features necessary for optimal wear comfort during physical activities.
Methods: A total of 12 young active women have participated in this study to don a changeable sports bra that allows adjustment of tension or replacement of the bra components. The skin and body core temperatures as well as heart rate for four bra conditions during treadmill running for 15 minutes at 8 km/h are recorded by using temperature and heart rate sensors. The subjectively perceived thermal and pressure comfort are evaluated by using a visual analog scale with ratings of 1 to 10.
Results: Following exercise, there is no change in core temperature for all of the bra conditions studied. Even though the body core temperature may increase due to the higher rate of heat production with muscular work done during treadmill running, the increase in heat dissipation tends to balance the increase in rate of metabolic heat production to maintain a stable core temperature. After a short duration of treadmill running, the change in skin temperature ranges from 0.22°C to 3.56°C amongst the 4 bra conditions. The shoulder strap area shows a slight change in skin temperature during exercise, and the participants are particularly sensitive to the increased pressure in this area, thus adversely affecting their ratings of the thermal and pressure comfort.
Conclusion: In this study, the increased bra pressure does not show significant change in core temperature and heart rate during short duration exercise. Even though the results are not statistically significant, the shoulder strap pressure is found to be related to the changes in skin temperature and subjective ratings of thermal and pressure comfort.

Keywords: Core body temperature, Sports bra, Pressure, Thermal comfort

LIU QL, **Yick KL**, Chan KC, Wong ST, Ng SP. (2022). Sports bra pressure: effect on core body temperature and comfort sensation. 13th International Conference on Applied Human Factors and Ergonomics, AHFE 2022, New York, USA, 24-28 July 2022.

AHFE 2024 International Conference

July 24-27, 2024 - Nice, France

Human Factos in Sports, Performance and Wellness, Vol. 150, 2024, 49–58
https://doi.org/10.54941/ahfe1005289

Approach for Evaluating Breast Motion for Sports Bra Design

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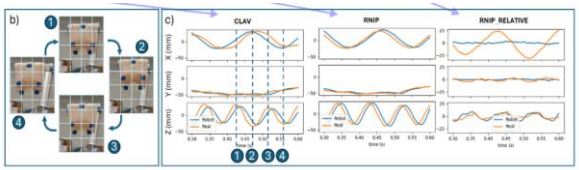
ABSTRACT

Traditional studies evaluating breast motion and bra performance have involved human subjects, but maintaining consistent results is challenging due to biomechanical limitations. Therefore, this study proposes an objective and reliable method to ensure consistent testing conditions for evaluating breast motion. This method involves designing a manikin with soft breast prostheses and incorporating with a commercial 6-degree-of-freedom robotic arm. Soft silicone rubber was used for fabrication of artificial breasts. Moreover, the robotic arm can replicate the movement of torso, and the soft breast prostheses can mimic that of female breast. The results show the breast prostheses of manikin close to the human breast in dynamic performance that was validated by the motion capture experiment. This new approach can be used for evaluating the sports bra to compare their supporting level.

Keywords: Body and breast motion, Sports bra evaluation, Silicone fabrication, Robotics, Motion capture, Six degree-of-freedom motion simulation



Hui KT, Cheah YT, **Yick KL**, Yip J, Ng Z. (2024). Approach of evaluating breast motion for sports bra design. AHFE 2024, July 2024.

Research Outputs | 02 Journal Papers

Lee CW, **Yick KL**, Ng SP, Yip J. (2020). Soft manikin as tool to evaluate bra features and pressure. International Journal of Fashion Design, Technology and Education, 13(2):204-212.

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Lee CW, **Yick KL**, Ng SP, Yip J. (2021). Analysis of dynamic vertical breast displacement for the design of seamless moulded bras. The Journal of The Textile Institute, 113(4):637-646.

Research Dissemination | 05 Journal Papers

sensors

MDPI

Article

Effect of Contacting Surface on the Performance of Thin-Film Force and Pressure Sensors

Ka Po Maggie Tang [1], Kit Lun Yick [1,2,*], Pui Ling Li [1], Joanne Yip [1], King Hei Or [1] and Kam Hong Chau [1]

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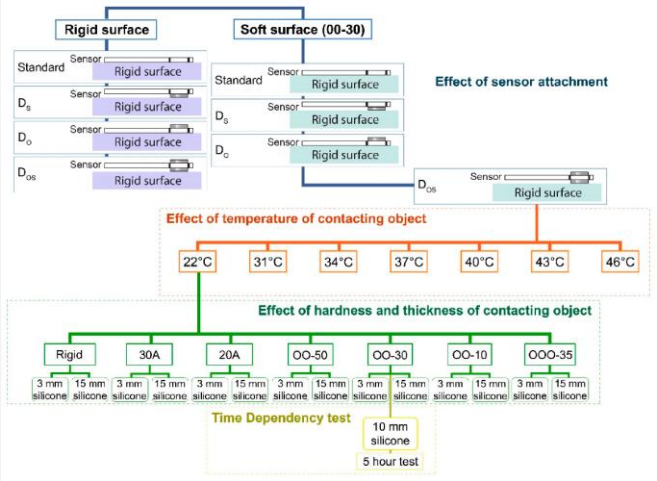

Tang KPM, **Yick KL**, Li PL, Yip J, Or KH, Chau KH. (2020). Effect of contacting surface on the performance of thin-film force and pressure sensors. Sensors, 20(23):6863.

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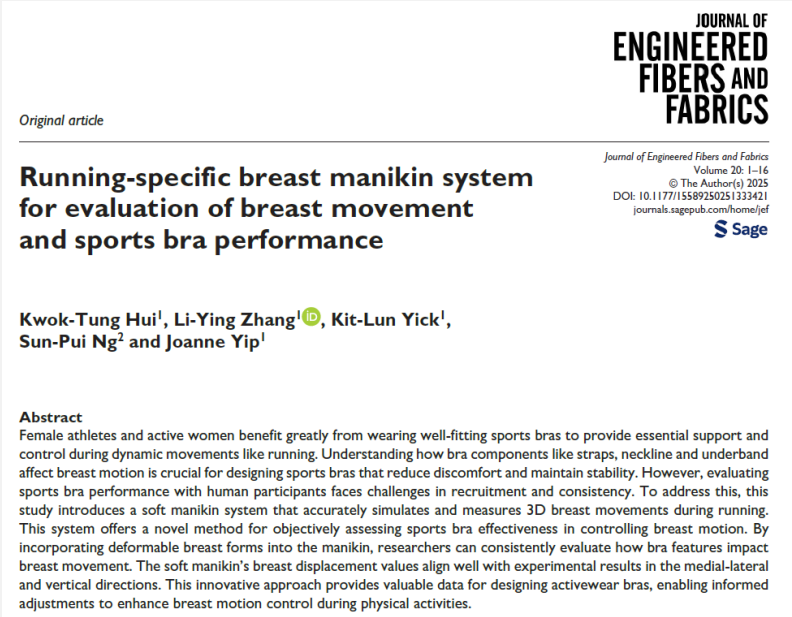
Zhang S, **Yick KL**, Yip J, Yu W, Tang KPM. (2021). An understanding of bra design features to improve bra fit and design for older Chinese women. Textile Research Journal, 91(3-4):406-420.

Research Outputs| 02 Journal Papers



JOURNAL OF ENGINEERED FIBERS AND FABRICS

Original article

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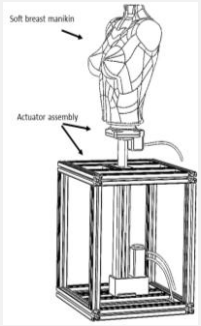
Running-specific breast manikin system for evaluation of breast movement and sports bra performance

Kwok-Tung Hui[1], Li-Ying Zhang[1], Kit-Lun Yick[1], Sun-Pui Ng[2] and Joanne Yip[1]

Abstract
Female athletes and active women benefit greatly from wearing well-fitting sports bras to provide essential support and control during dynamic movements like running. Understanding how bra components like straps, neckline and underband affect breast motion is crucial for designing sports bras that reduce discomfort and maintain stability. However, evaluating sports bra performance with human participants faces challenges in recruitment and consistency. To address this, this study introduces a soft manikin system that accurately simulates and measures 3D breast movements during running. This system offers a novel method for objectively assessing sports bra effectiveness in controlling breast motion. By incorporating deformable breast forms into the manikin, researchers can consistently evaluate how bra features impact breast movement. The soft manikin's breast displacement values align well with experimental results in the medial-lateral and vertical directions. This innovative approach provides valuable data for designing activewear bras, enabling informed adjustments to enhance breast motion control during physical activities.



Hui KT, Zhang LY, Yick K, Yip J. (2025). Running-specific breast manikin system for evaluation of breast movement and sports bra performance. Journal of Engineered Fibers and Fabrics, 20:1-16.

Sun Y, **Yick KL**, Cai Y, Yu W, Chen L, Lau N, Zhang S. (2021). Finite element analysis on contact pressure and 3D breast deformation for application in women's bras. Fibers and Polymers, 22(10):2910-2921.

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Research Outputs | 03 Patents

Chinese Patents

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发 明 人：易洁伦;叶晓云;吴新培;许国栋

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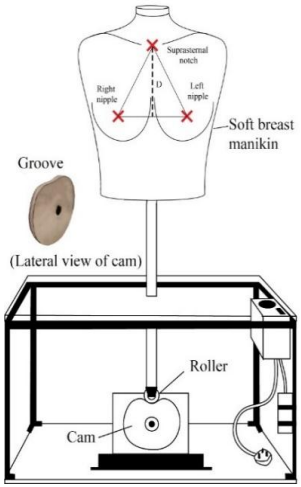
Three Chinese patents (Nos. 202010742991.6, 202210893024.9 and 202510525704.9) have been granted or filed for system design, an algorithm for the breast control index and robotic replications in different sports.

Research Outputs: Evolution of the Soft Manikin Design

2019 Nov — Prototype I



2.5–4.2 km/h running speed

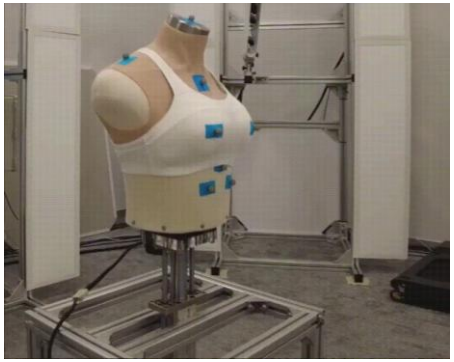
- Models the vertical dynamic movement of the breasts, moving up and down in a continuous repeatable motion.
- Its motion is governed by a **concave cam profile** based on the extracted waveform pattern.
- The simulated walking speed ranges **from 2.5 to 4.2 km/h**.

2020 Dec — Prototype II

6 km/h running speed

- The simulated running speed increased to **6 km/h**.
- Motion parameters and the peak and valley of displacements are measured with a **variation of less than 5%.**
- Includes inputs of human motion coordinates.

2022 Jun — Prototype III



VIDEO Link

10 km/h running speed

- The simulated running speed increased to **10 km/h**.
- The 3dBMS motion replicates trajectories of human running in vertical, rotational and leaning directions, with **strong correlation coefficients ($r^2 > 0.966$)**.

2025 Jan — Prototype IV

VIDEO Link

Multiple motions

- By using a robotic manipulator, the system can **replicate varying body motions during various sports activities** repeatably and consistently.

Research Field and Key References

Research Field

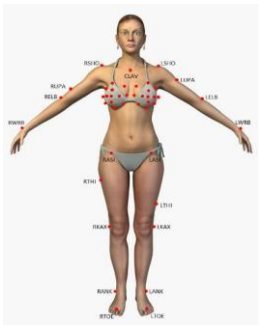
Research Context and Intellectual Positioning

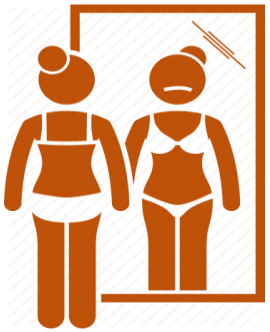
Breast biomechanics research has gained prominence due to widespread exercise-induced breast discomfort, as reported by 44%–72% of women and 44% of elite female athletes (Brisbine et al., 2020; Scurr et al., 2014; Chen et al., 2019). Despite this urgency, critical gaps persist, including the following:

1. **Design Limitations**: Current sports bras fail to adequately control excessive breast motion during exercise, with 90% of women across breast sizes wearing ill-fitting bras (Coltman et al., 2018), highlighting systemic flaws in biomechanical integration during product development (Norris et al., 2021).
2. **Methodological Constraints**: Research validity is compromised by inconsistent biomechanical protocols (e.g. static postures vs. dynamic activities) and confounding factors in pressure measurement, such as posture variability and subjective preferences (Zhang et al., 2009). McGhee and Steele (2020) further critique the field's reliance on poorly designed studies, which hinder translational advancements.
3. **Original Contribution**
   By rectifying the methodological shortcomings identified in prior studies (McGhee & Steele, 2020), this work provides novel protocols for quantifying breast kinematics and bra-body interactions under real-world exercise conditions. These insights challenge the status quo of 'one size fits all' bra design paradigms and offer actionable solutions to improve women's athletic performance and health outcomes.

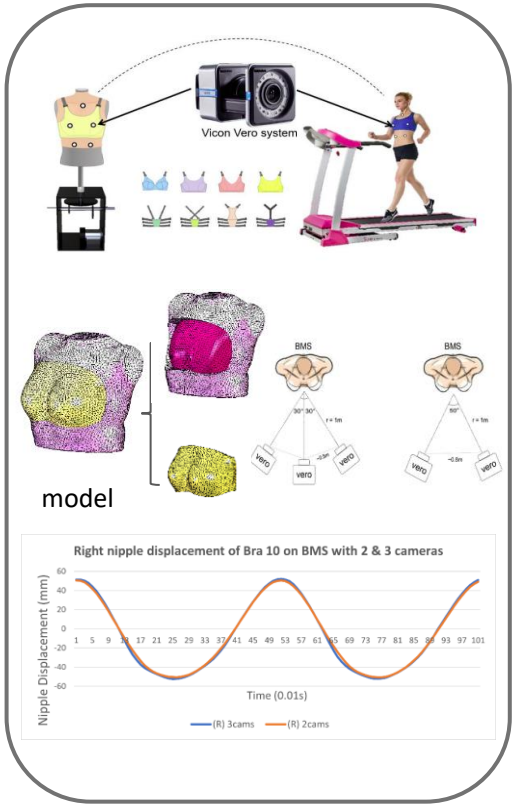
Key References

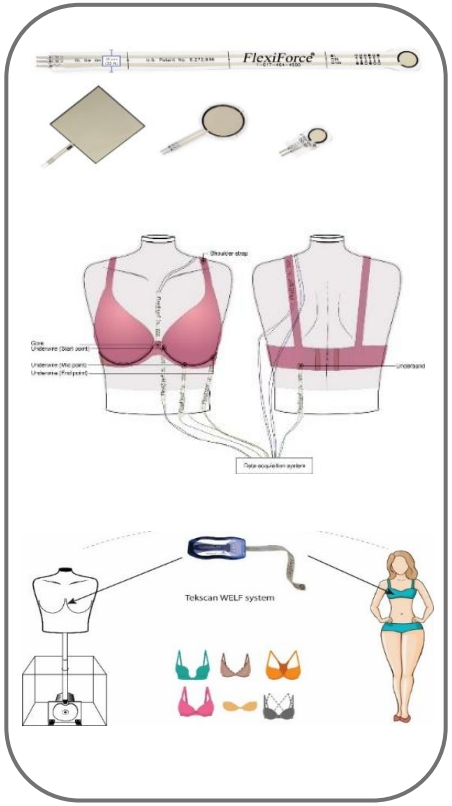
- Brisbine BR, Steele JR, Phillips EJ, (2020). Breast pain affects the performance of elite female athletes. Journal of Sports Sciences, 38(5):528-533.
- Chen X, Wamg J, Wang Y. (2019). Breast pain and sports bra usage reported by Chinese women: why sports bra education programs are needed in China. Fibres & Textiles in Eastern Europe, 27(4):17-22.
- Coltman CE, Steele JR, McGhee DE. (2018). Which bra components contribute to incorrect bra fit in women across a range of breast sizes. Clothing and Textiles Research Journal, 36(2):78-90.
- McGhee DE, Steele JR. (2020). Biomechanics of breast support for active women. Exercise and Sport Sciences Reviews, 48(3):99-109.
- Norris M, Blackmore T, Horler B, Wakefield-Scurr J. (2021). How the characteristics of sports bras affect their performance. Ergonomics, 64(3):410-425.
- Scurr J, Hedger W, Morris P (2014). The prevalence, severity, and impact of breast pain in the general population. The Breast Journal, 20(5):508-513.
- Zheng R, Yu W, Fan J. (2009). Pressure evaluation of 3D seamless knitted bras and conventional wired bras. Fibers and Polymers, 10(1), 124-131.

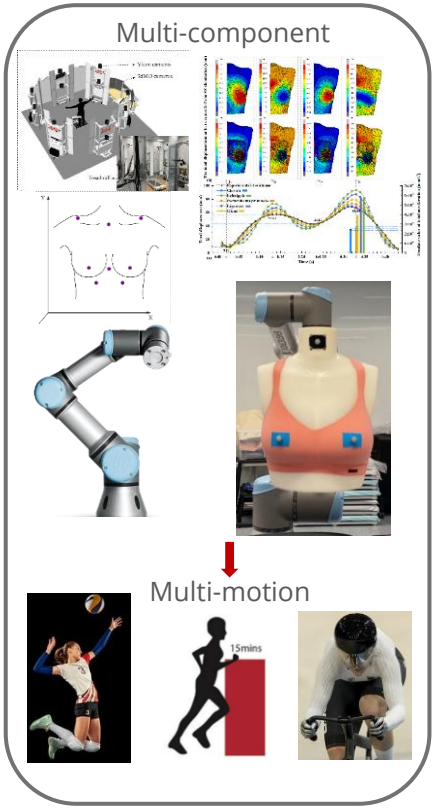




Research Methods, Prototypes and Materials







Phase I

a. Silicone breasts design
b. Human motion analysis
c. 3D dynamic body movement simulator (3dbms) design

Phase II

a. Optimised motion track system
b. 3dBMS validation
c. Algorithms for assessing bra performance

Phase III

a. Customised pressure sensors for measuring body-bra pressures
b. Analysis of bra pressure and comfort

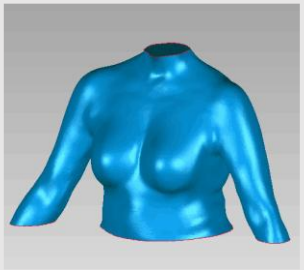
Phase IV

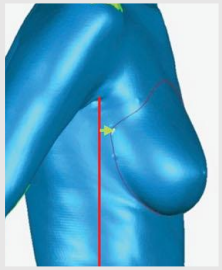
a. Multi-motion activities, including running, jumping and cycling
b. Evaluation of the support levels of sports bras

Research Methods, Prototypes and Materials

Phase Ia: Design of Silicone Breasts

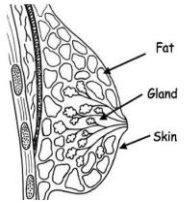
This phase aims to characterise the **breast shape geometry** and material properties of **soft breast tissues** to replicate the dynamic displacement of the human breasts (with a bra size of 36C).

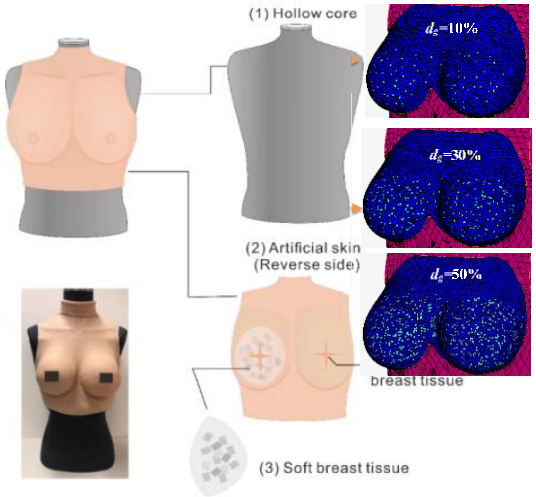


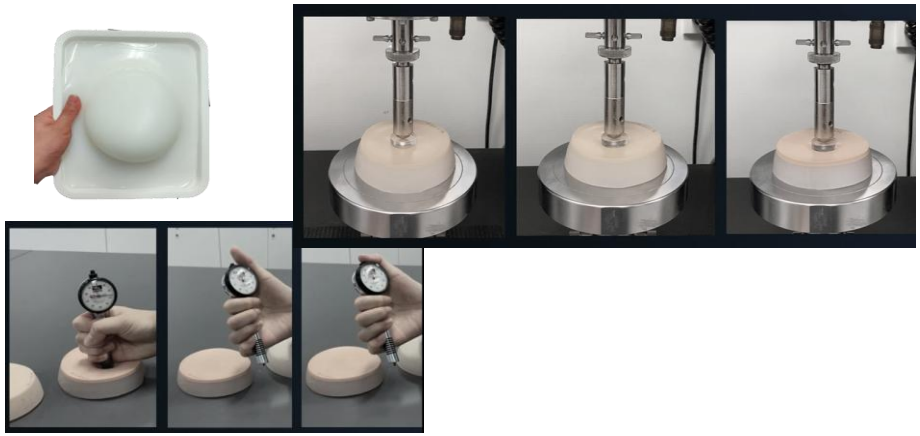


Fabrication of silicone samples for manikin breasts

Encapso K+2s	Encapso K+3s	Encapso K+4s
Gel+0010	Gel+0010+1s	Gel+0010+2s
Gel2		Gel2+0.5s
Gel+0.5s	Gel+1s	Gel+1.5s







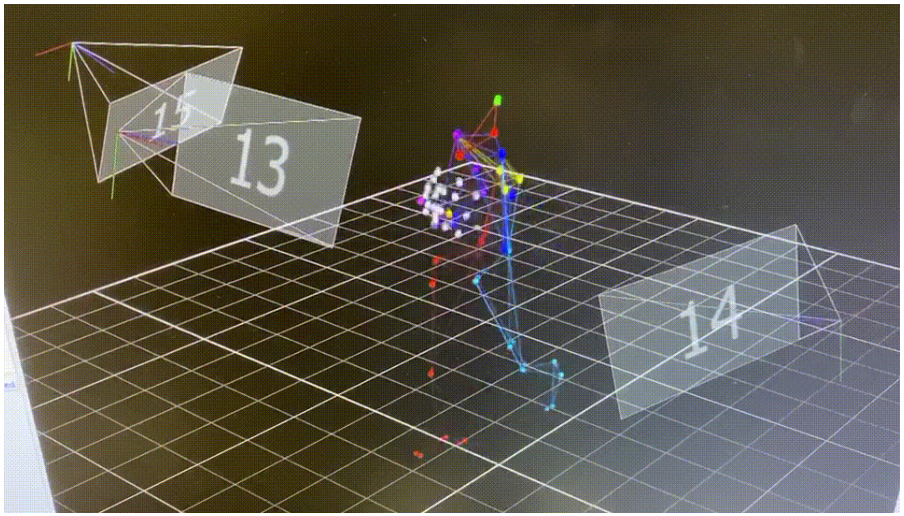
Related Journal Paper:
Lee CW, **Yick KL**, Ng SP, Yip J. (2020). Soft manikin as tool to evaluate bra features and pressure. International Journal of Fashion Design, Technology and Education, 13(2):204-212.

Research Methods, Prototypes and Materials

Phase Ib: Analysis of Human Motion and Bra Support

This phase aims to define the motion range of **human subjects** during various running speeds (from 4 to 10 km/h):

- Maximum vertical displacement: **100 mm at the clavicle** and **140 mm at the nipple**
- Shoulder/trunk rotation: **±15.5°** at maximum, with a leaning angle of **5°**
- Significant motion differences exist between the subjects (all in bra size of 36C) and at **various bra conditions**.



Motion measurements of the human body and breasts under 30 bra conditions at various running speeds

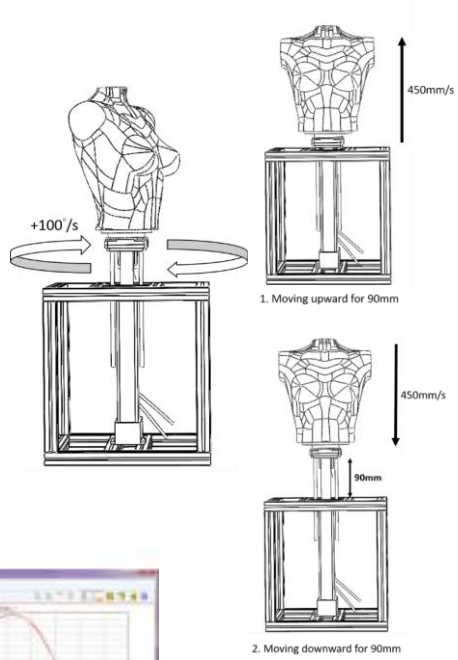
Related Conference Paper:

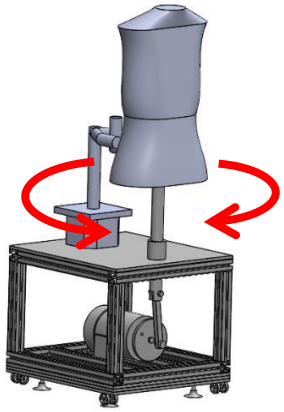
Sun Y, Yick KL, Tang KPM, Yu A, Yip J, Ng SP. (2020). Control performance of different bra designs and materials during physical activity. AATCC-SIFTIC 2020. October 15–17, Shanghai, China.

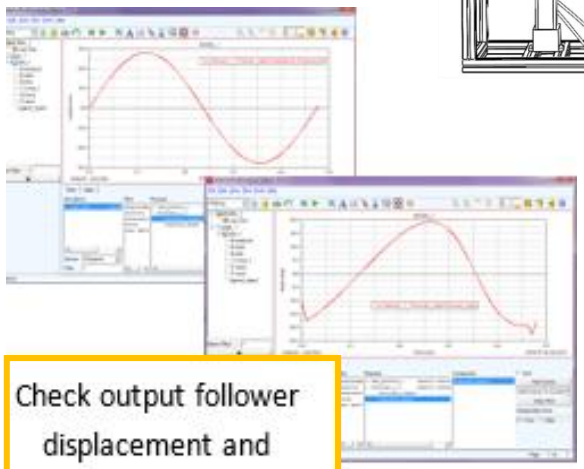
Research Methods, Prototypes and Materials

Phase Ic: Design of the 3D Dynamic Body Movement Simulator (3dBMS)

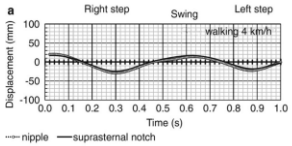
With reference to the running motions of human subjects, the **motion range of the 3dBMS** are specified to mimic the trunk movement that corresponds to the rhythm of body motion in running.

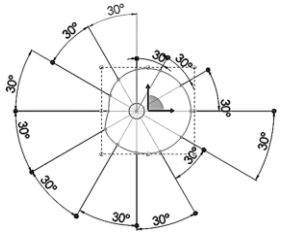


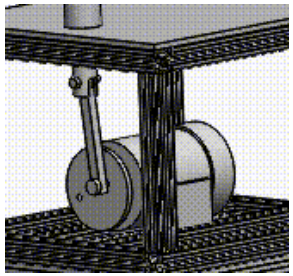


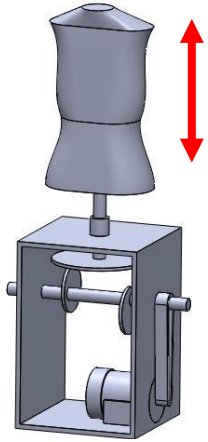


Check output follower displacement and pressure angle







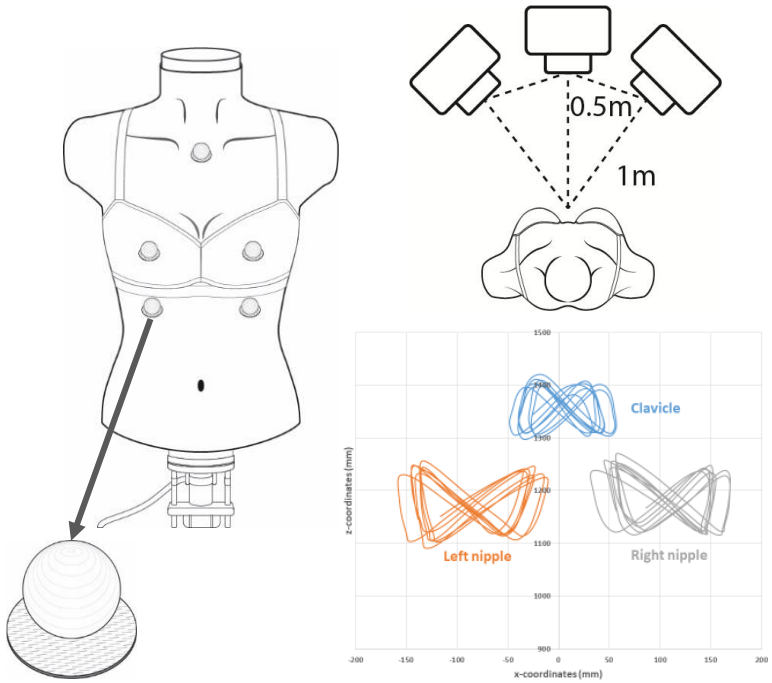


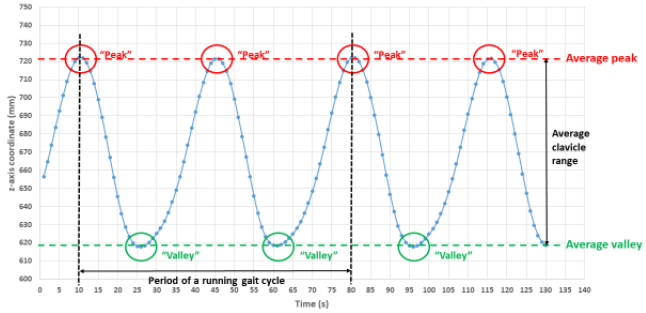
Related Journal Paper:

Lee CW, **Yick KL**, Ng SP, Yip J. (**2021**). Analysis of dynamic vertical breast displacement for the design of seamless moulded bras. Journal of the Textile Institute, 111(10):1470-1480.

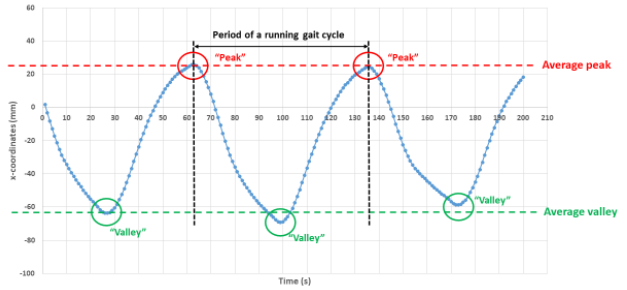
Research Methods, Prototypes and Materials

Phase IIa: Optimised Motion Track System



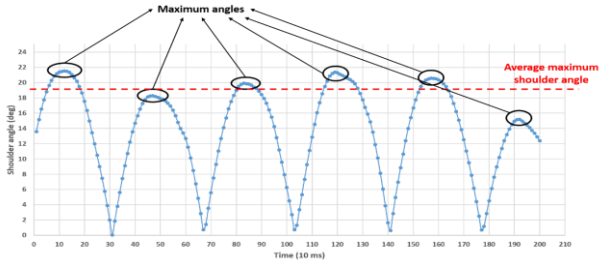


A graph of z-coordinates of the clavicle marker in 1.3 seconds



A graph of the *x*-coordinates of the clavicle marker in 2 seconds

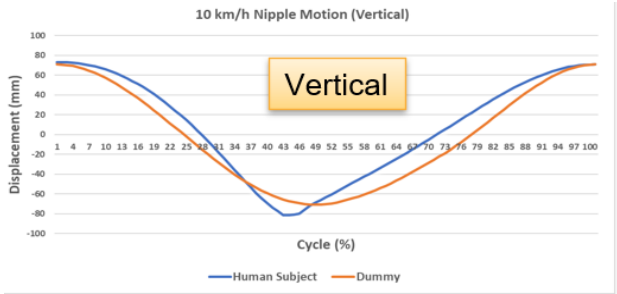
- This phase aims to optimise the locations of **body landmark and motion cameras** for effective tracking of 3D body position and breast motion.
- A **breast control percentage** is formulated to determine the level of control of breast displacements in the *X*, *Y*, and *Z* directions of the bra.



Shoulder angles in 2 seconds

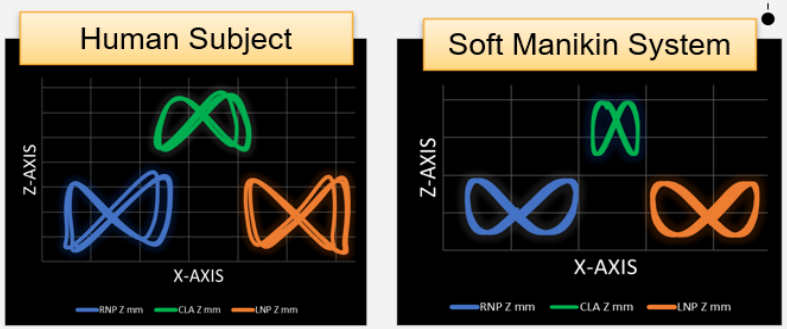
Research Methods, Prototypes and Materials

Phase IIb: Validation of the Dynamic Manikin System



Human data vs **Dummy (3dBMS)**

- R^2 = 0.9663 (vertical)
  R^2 = 0.9961 (rotational)
  R^2 = 0.9710 (leaning)
- Strong relationship between the human data and the 3dBMS at three directions



- Repeating human trunk motion trajectories like an infinity symbol, or a lemniscate (∞) from front view (i.e. the x-z plane)
- **RESULTS: 3dBMS is capable of imitating trajectories performed by human running**

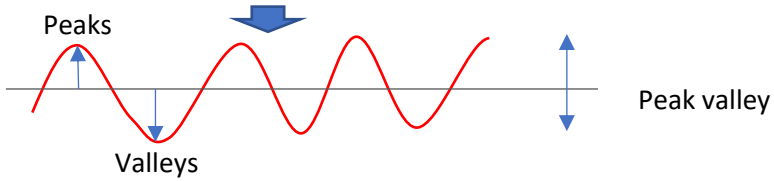
Related Journal Paper:
Sun Y, **Yick KL**, Cai Y, Yu W, Chen L, Lau N, Zhang SC. (2021). Finite element analysis on contact pressure and 3D breast deformation for application in women's bras. Fibers and Polymers, 22(10):2910-2921.

Research Methods, Prototypes and Materials

Phase IIc: Breast Control Performance of Bras

This phase aims to develop **an index of breast displacement** to facilitate the comparison of bra designs and communication amongst industry partners.

Nipple coordinates – clavicle coordinates



$$\text{Relative nipple displacement (RND)} = \frac{\text{Peak} - \text{Valley (Nipple coordinate} - \text{Clavicle coordinate)}}{\text{Clavicle displacement}} \times 100\%$$

$$\text{Percentage of change in nipple displacement (PND)} = \frac{A_n - A_b}{A_n} \times 100\%,$$

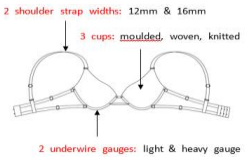
where A_n represents the relative nipple displacement (RND) in braless condition, and A_b is the RND in bra-wearing condition.

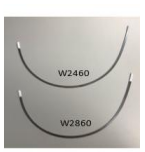
Findings:

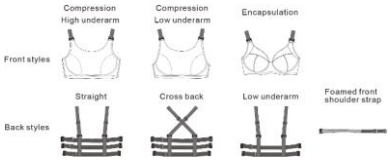
- The choice of cup fabric, shoulder strap width and underband tension have major effects on the control of breast displacement.
- Woven bra cups with a narrow strap show good performance in controlling excessive breast displacement during motion.

Changeable bra style No.	Cup material	Strap width (cm)	Wire No.
Bra 21	Moulded	1.2	W2460
Bra 22			W2860
Bra 23		1.6	W2460
Bra 24			W2860
Bra 25	Woven	1.2	W2460
Bra 26			W2860
Bra 27		1.6	W2460
Bra 28			W2860
Bra 29	Knitted	1.2	W2460
Bra 30			W2860
Bra 31		1.6	W2460
Bra 32			W2860

Changeable bra style no.	Front panel style	Shoulder Strap material	Shoulder strap style
Bra 11	Compression (moulded cups) - high underarm	Elastic strap	Straight
Bra 12			Cross back
Bra 13		Foamed front strap	Straight
Bra 14			Cross back
Bra 15	Compression (moulded cups) - low underarm	Elastic strap	Straight
Bra 16			Cross back
Bra 17		Foamed front strap	Straight
Bra 18			Cross back
Bra 19	Encapsulation (cut and sewn cups)	Elastic strap	Straight
Bra 20			Cross back
Bra 21		Foamed front strap	Straight
Bra 22			Cross back



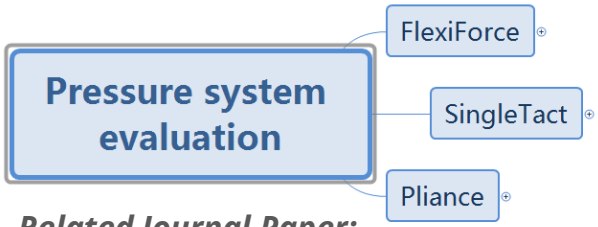




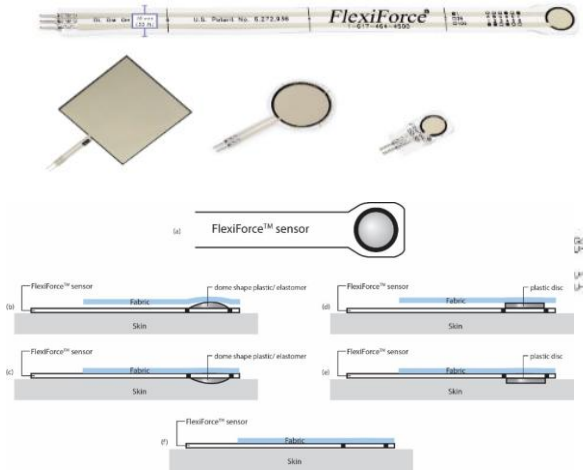
Research Methods, Prototypes and Materials

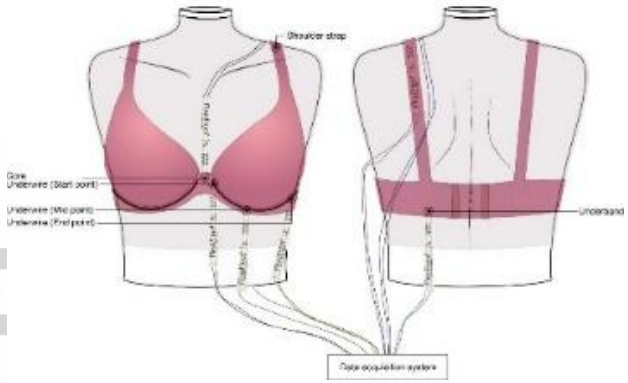
Phase IIIa: Evaluation of Bra Pressure and Comfort

This phase aims to characterise **the contact pressure induced by different bra designs and properties** by using a low-cost reliable force or pressure sensor.

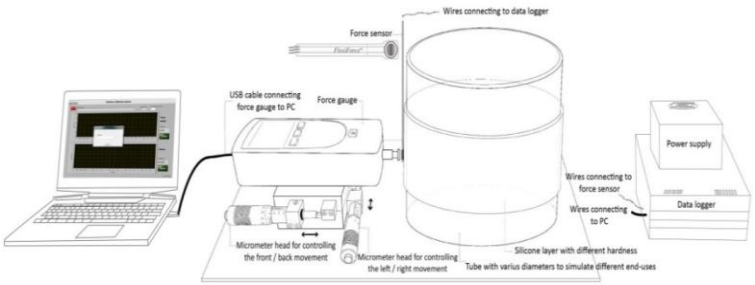


Related Journal Paper:





Company name	Model No.	Sensor type	Principle	Operating range	Active sensing area (mm)	Thickness (mm)
Tekscan (USA)	FlexiForce A201-1	Force sensor	Electrical resistance	0–454 g	9.53	0.203
SingleTact (USA)	S8-10N	Force sensor	Capacitance	0–1000 g	8	0.35
Novel.de (Germany)	Pliance X	Pressure sensor	Capacitance	0.5–60 kPa	10	0.95

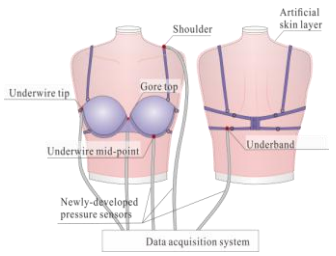


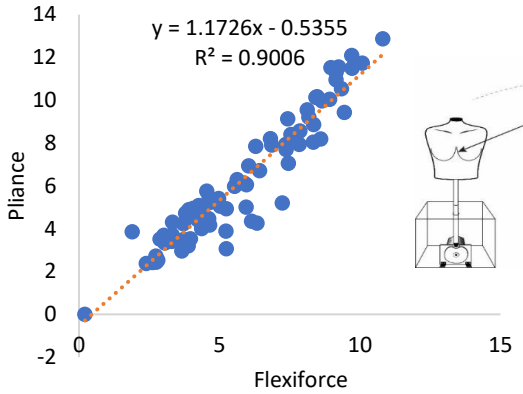
Related Journal Papers:

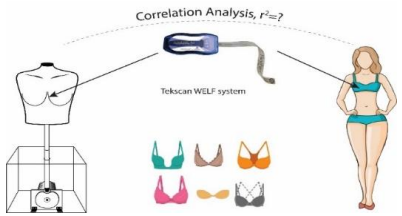
- Tang KPM, **Yick KL**, Li PL, Yip J, Or KH, Chau KH. (2020). Effect of contacting surface on the performance of thin-film force and pressure sensors. Sensors, 20(23):6863.

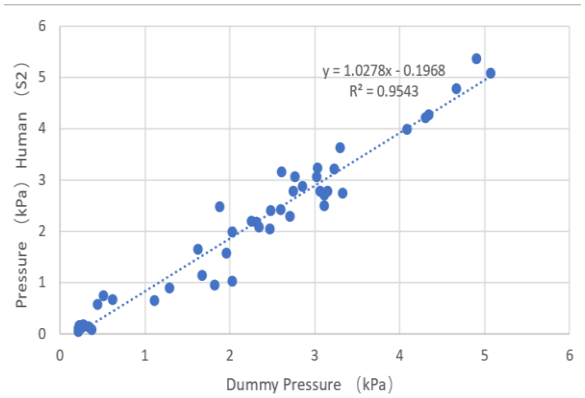
Research Methods, Prototypes & Materials

Phase III - b: Evaluation of Bra Pressure and Comfort









Findings:

- Use of soft breast manikin system for evaluation of bra pressure improve the reliability and variations induced by human body
- Flexiforce show a strong linear relationship with pressure data measured by Pliance-X (R^2=0.9)
- Tension in underband and shoulder straps significantly increase bra-skin pressures but resulting in positive sensation towards bra pressure comfort and breast support during exercise.

	Pressure (kPa) Mean ± SD (range)	Rating (1=the least comfort, 7=the best comfort) Mean ± SD (range)
Shoulder strap	2.33 ± 1.60 (0.25-10.41)	5.53 ± 1.36 (2.0-7.0)
Wire-mid	0.29 ± 0.36 (0.03-2.03)	5.30 ± 1.58 (2.00-7.00)
Wire-tip	2.88 ± 1.20 (1.08-7.37)	5.48 ± 1.35 (3.00-7.00)
Underband	1.61 ± 0.85 (0.60-4.04)	5.30 ± 1.56 (1.00-7.00)
Gore top	1.40 ± 0.80 (0.21-4.99)	4.10 ± 1.65 (1.00-7.00)

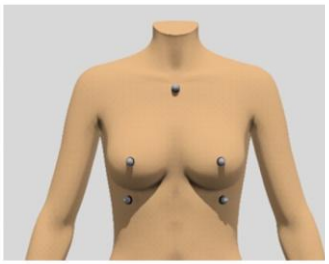
Related Papers:

- LIU QL, Yick KL, Chan KC, Wong ST, Ng SP. (**2022**). Sports bra pressure: effect on core body temperature and comfort sensation. AHFE 2022, New York, USA, 24-28 July 2022.
- Zhang SC, Yick KL, Yip J, YU W, Tang KPM. **(2021).** An understanding of bra design features to improve bra fit and design for Chinese older women. *Textile Research Journal*. 91(3-4):406-420.

Research Methods, Prototypes and Materials

Phase IVa: System for Multiple Motions with Multi-Component

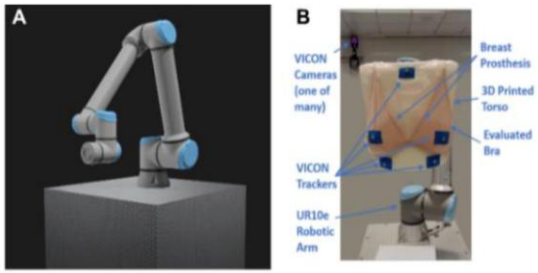
- Designing a manikin with soft breast prostheses and incorporating with a commercial 6-DOF robotic arm.
- A soft silicone rubber was used for the fabrication of artificial breasts.

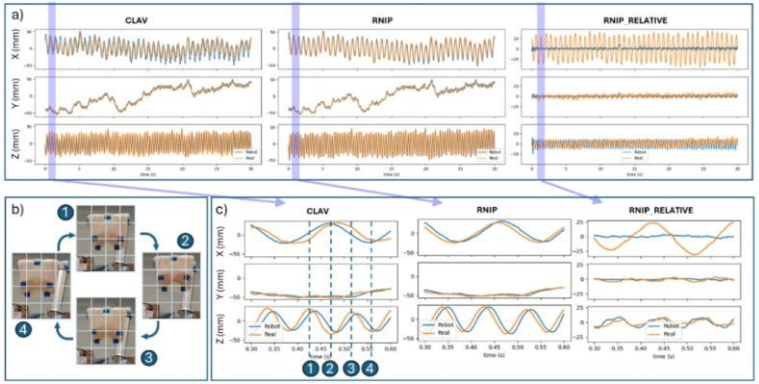


$$ {}^{c}\hat{z} = \frac{{}^{C}CD}{||{}^{C}CD||}, {}^{c}\hat{x} = \frac{{}^{C}CB}{||{}^{C}CB||}, {}^{c}\hat{y} = {}^{c}\hat{z} = \times {}^{c}\hat{x} $$

The three unit-vectors are concatenated together to form the rotation matrix that describes the pose of the upper torso

$$ {}^{c}_{0}R = \begin{bmatrix} {}^{c}\hat{x}_1 & {}^{c}\hat{y}_1 & {}^{c}\hat{z}_1 \\ {}^{c}x_2 & {}^{c}\hat{y}_2 & {}^{c}\hat{z}_2 \\ {}^{c}\hat{x}_3 & {}^{c}\hat{y}_3 & {}^{c}\hat{z}_3 \end{bmatrix} $$





Experimental results for comparing human and robot marker motions

Findings:

- The robotic arm can replicate the movement of the torso, and the soft breast prostheses can mimic that of the female breast.
- This new approach can be used for evaluating sports bras to compare their support levels across various sports.

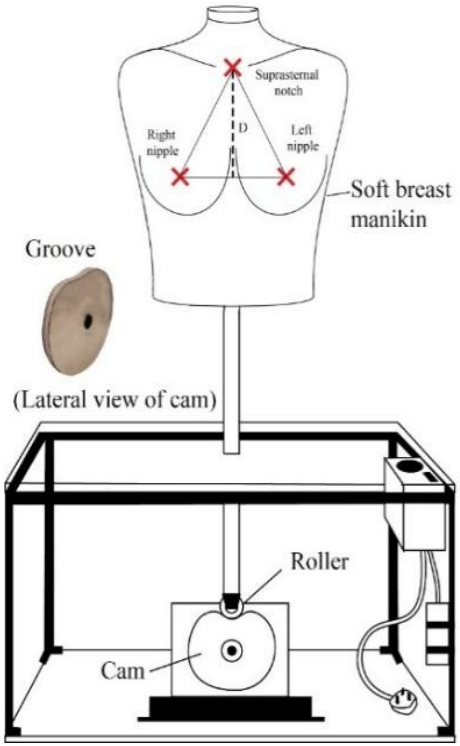
Related Papers:

Hui KT, Cheah YT, Yick KL, Ng SP, Yip J, Ching H. (**2024**). Approach of evaluating breast motion for sports bra design. The 15th International Conference on AHFE, Nice, France, July 24–27, 2024.

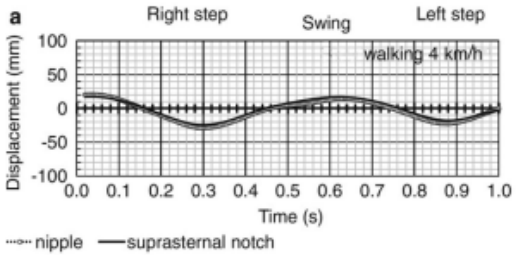
Hui KT, Zhang LY, Yick K, Yip J. (2025). Running-specific breast manikin system for evaluation of breast movement and sports bra performance. Journal of Engineered Fibers and Fabrics, 20:1-16.

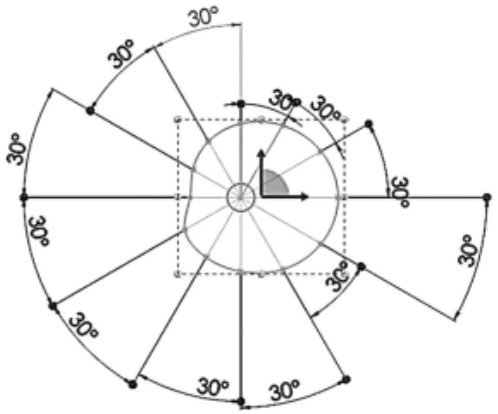
Research Methods, Prototypes and Materials

Dynamic Manikin System - Prototype I (November 2019)



The motion of the manikin is governed by the shape profile of the groove.





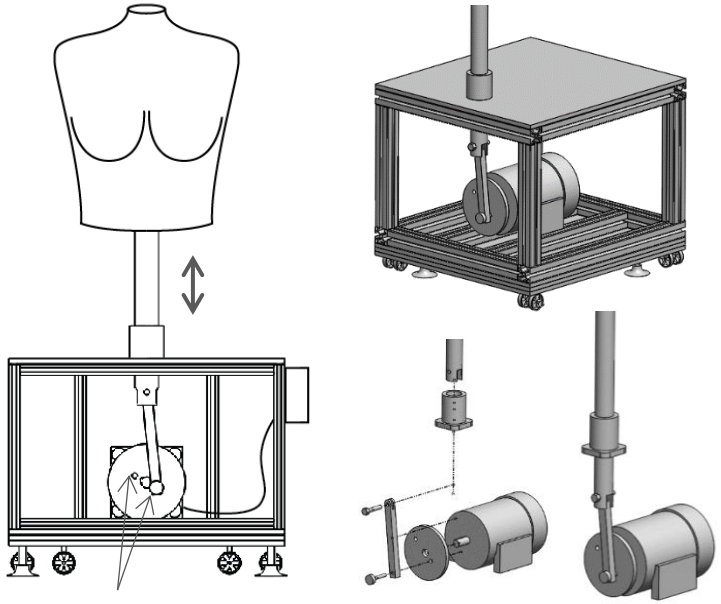
Displacement–time graph of the breast for a human subject walking at 4 km/h and the derived cam profile design to simulate the vertical breast movement.

Features:

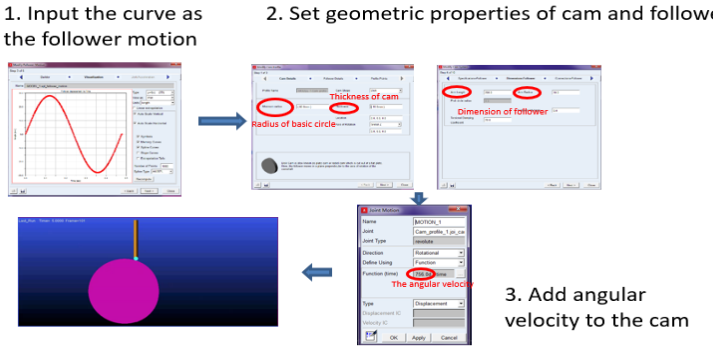
- The manikin is designed to model the vertical dynamic movement of the breasts, which can move up and down in a continuous repeatable motion.
- A pneumatic system is used with an auxiliary mechanical device to give the manikin dynamic movement.
- Its motion is governed by a **concave cam profile** based on the extracted waveform pattern.
- The simulated walking speed ranges **from 2.5 to 4.2 km/h**.

Research Methods, Prototypes and Materials

Dynamic Manikin System - Prototype II (December 2020)



Dummy connecting points with a different distance from the centre of origin on the circular cam.



Features:

- The concave profile of the cam in Prototype I resulted in an uneven motion, adversely affecting the rhythm of the motion of the BMS.
- On the basis of a multibody dynamic simulation software, the cam design is revised to a **circular shape** for improved motion.
- The simulated running speed can be increased to **6 km/h**.
- Motion parameters, including the peak and valley of displacement, the peak and valley of velocity, the peak and valley of acceleration, and stride frequency are measured with a **variation of less than 5%.**

Research Methods, Prototypes & Materials

Dynamic Manikin System - Prototype II (December 2020)

In describing the variation of the moving distance of the simulator, the **coefficient of multiple determinations (CMD)** was used to measure the similarity of the kinetic data of the breast motion by the simulator. This value ranged from 0 to 1, in which the CMD value is calculated using the equations below:

$$R^2_{\square} = 1 - \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(D_{ij}-\bar{D}_j)^2/N(M-1)}{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(D_{ij}^{\square}-\bar{D}\right)^2/(MN-1)}$$

$$\bar{D}_j = \frac{1}{M}\sum_{i=1}^{M} D_{ij}$$

$$\bar{D} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} D_{ij}$$

where D_{ij} is the *j*th time point of the *i*th trial.

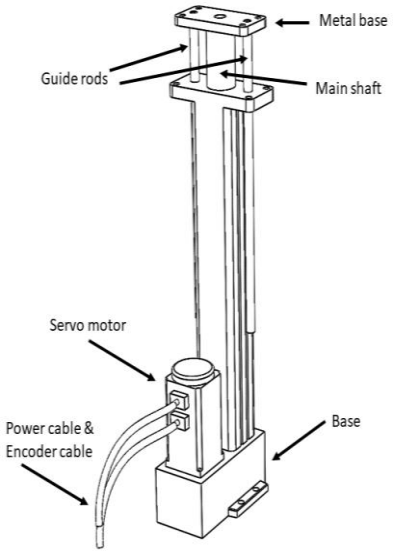
	Clavicle		Nipple	
	4km/h	6km/h	4km/h	6km/h
Vertical displacement (mm)	0.9994	0.9979	0.9988	0.9975
Vertical velocity (mm/s)	0.9933	0.9974	0.9983	0.9958
Vertical acceleration (mm/s^2)	0.9745	0.9946	0.9668	0.9885

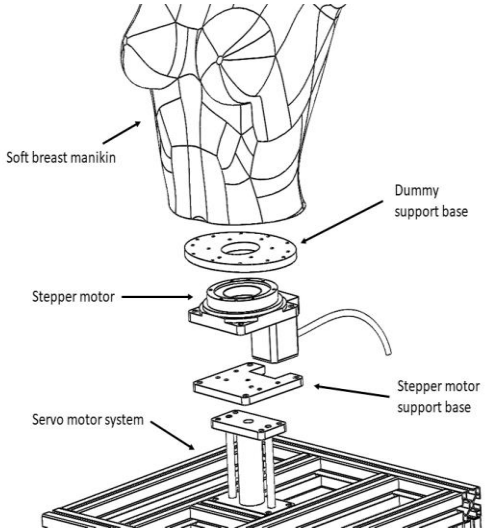
Findings:
The CV values of the clavicle and nipple motion data are less than 5%. The motion data of the clavicle and nipple exhibited a high level of repeatability, with CMDs ranging from **0.9668 to 0.9994**.

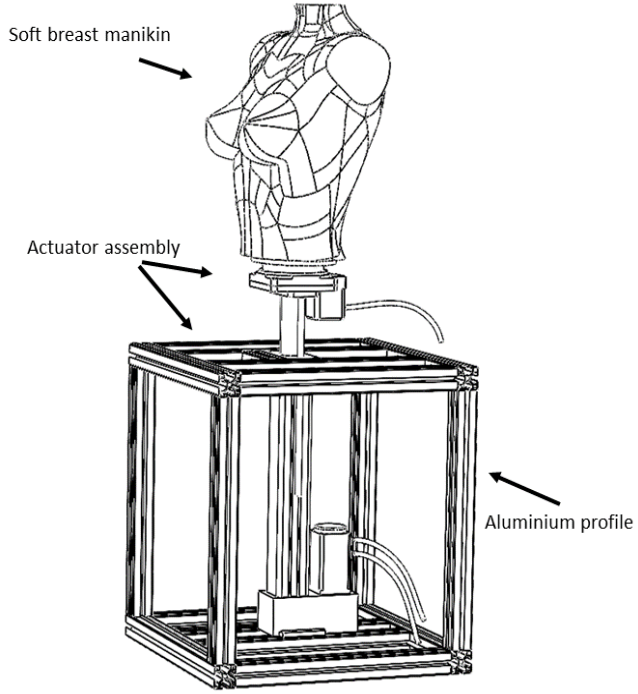
Related Patent:
Chinese Patent, 202210893024.9 "用于评估文胸支撑性能的人体模型系统及评估方法". *Granted* (2025)

Research Methods, Prototypes and Materials

Dynamic Manikin System - Prototype III (June 2022)





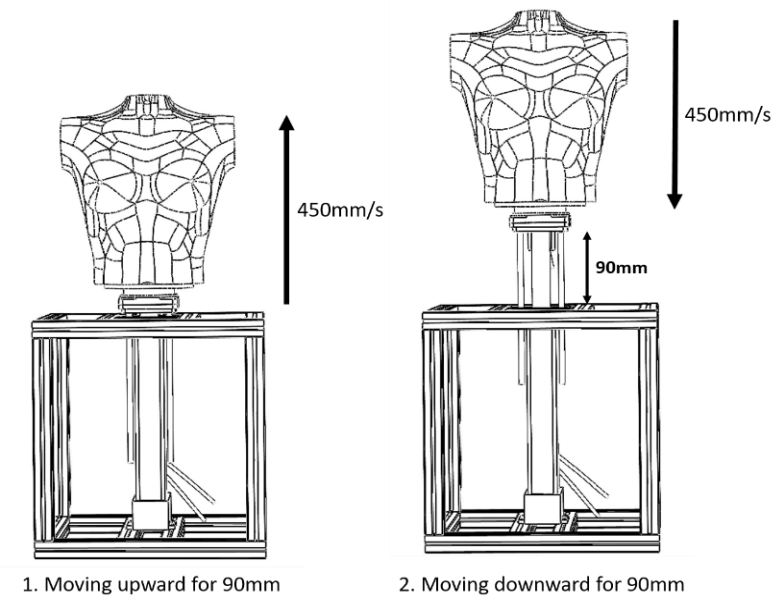


Features:

- The vertical and rotation motions of the manikin is controlled by the 2-axis motor controller, which is a programmable device that can be coordinated in a predetermined manner with the motion of an electric motor.
- To simulate the running motion by the vertical motion shaft and rotational step motor, the shaft moves up and down in a specific distance with a designed speed to control the manikin's vertical motion, and the step motor repeats the rotation with a specific angle in clockwise and counterclockwise directions to simulate the shoulder rotation of the human body in running motion.

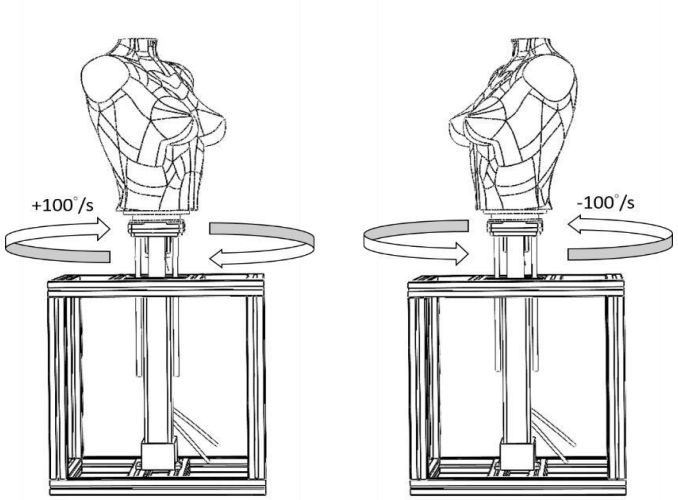
Research Methods, Prototypes and Materials

Dynamic Manikin System - Prototype III (June 2022)



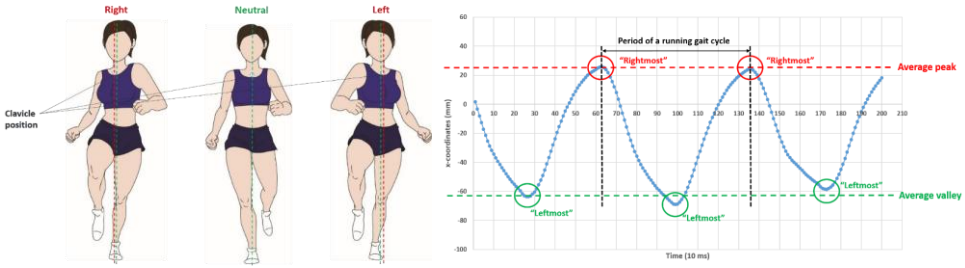
1. Moving upward for 90mm
2. Moving downward for 90mm

The 3dBMS can replicate the human running motion in vertical and rotation directions at the speeds of 4, 6 and 10 km/h.

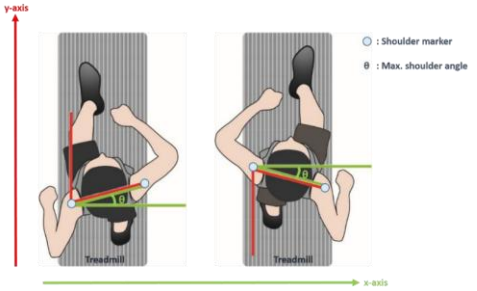


1. Rotating clockwise for 40°
2. Rotating anticlockwise for 40°

The 3D coordinates of the body landmarks during running are precisely quantified for design inputs of the 3dBMS.

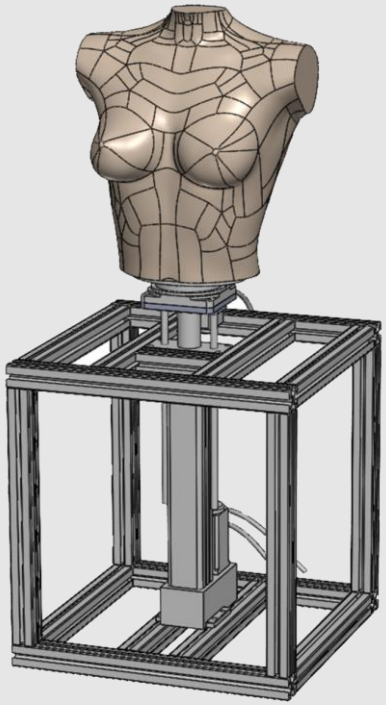


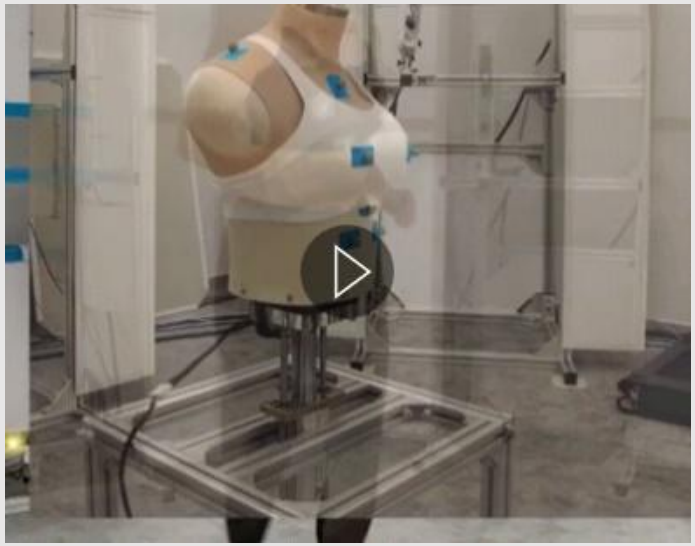
Measuring the shoulder and trunk rotations in running motion.

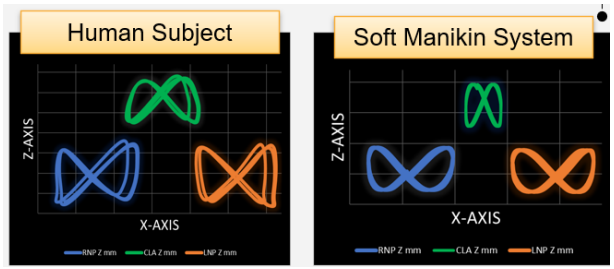


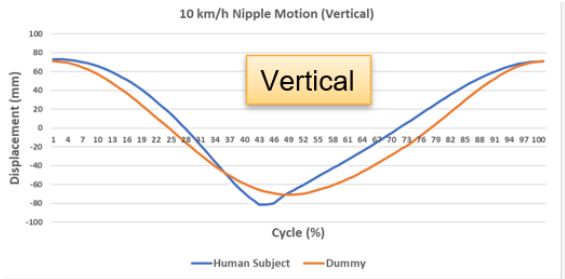
Research Methods, Prototypes and Materials

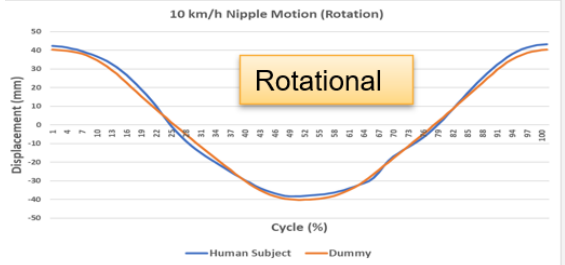
Dynamic Manikin System - Prototype III (June 2022)

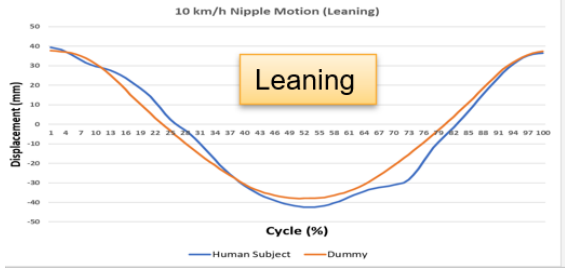












Features of the **3dBMS :**

- The simulated running speed is increased to **10 km/h**.
- The motion in vertical, rotational and leaning directions of the 3dBMS can successfully replicate trajectories of the human body in running motion, with a strong correlation coefficient **($r^2 > 0.966$)**

Research Methods, Prototypes and Materials

Dynamic Manikin System - Prototype III (June 2022)

3DBMS Bra Evaluation Report

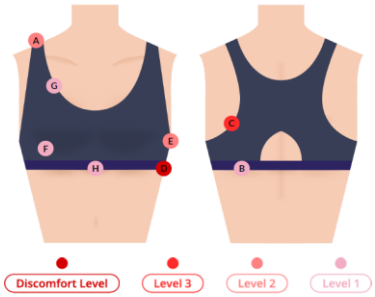
2023-02-15 15:44:11

Sample Name	B03	Bra Style	SportsBra

Bra Photo and Sample Description

Moulded knitted fabric & foam cup;
Crossed back with adjustable elastics;
Knitted fabric & mesh laminated;
3x2 Hook & eye;

Pressure (kPa) in Each Measuring Point



3DBMS Bra Evaluation Report

2023-02-15 15:44:11

Point Pressures

Location	Description	Pressure(kPa)
High Tolerance		
Point A	Shoulder Strap	4.70
Point B	Underband	2.67
Moderate Tolerance		
Point C	Upperband	2.88
Point D	Side Seam	3.93
Point E	Armhole	2.21
Low Tolerance		
Point F	Bra Cup	0.00
Point G	Neckline	0.00
Point H	Gore	0.00

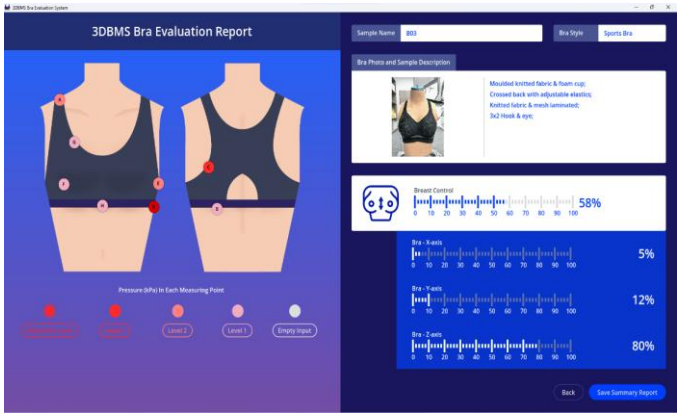
Breast Control

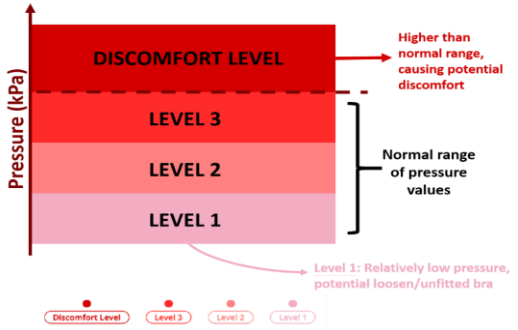
58%

Bra - X-axis
5%

Bra - Y-axis
12%

Bra - Z-axis
80%





Algorithms of bra performance from **the 3dBMS:**

- Formulation of breast control algorithms based on the 3D motion data for quantification of bra performance
- Pressure sensation and tolerance at different body regions classified into high/moderate/low tolerance points in relation to the levels of discomfort induced by bra pressures

Research Methods, Prototypes & Materials

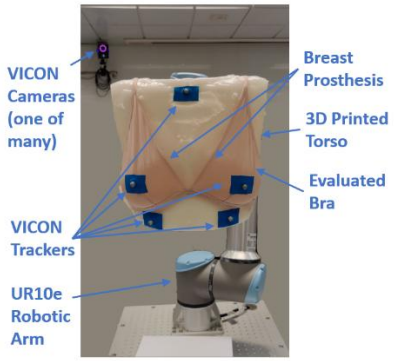
Dynamic Manikin System - Prototype IV (January 2025)

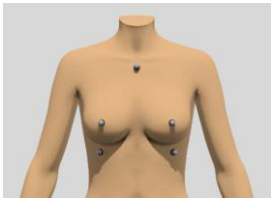
Features of the **artificial torso model:**

- 3D body scanning with breast volume control of from a digital female avatar
- 3D printed PLA shell mould for a tailored torso model
- Casting and fabrication of silicone breasts and skin layer based on their mechanical properties and deformation behaviour



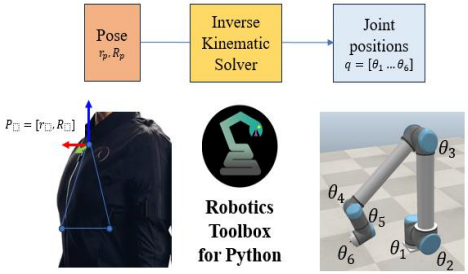




An UR10e model from Universal Robots





Features of **Dynamic Motion :**

- The dynamic motion of the torso model is controlled by a robotic manipulator. It can replicate the body motions during various sports activities repeatably and consistently.
- With inputs of human motion coordinates, the UR10e robotic arm can successfully simulate the running and walking motions.

Research Outcomes, Findings and Further Research

Research Outcomes:

The dynamic manikin system design successfully replicates the 3D body positioning and posture changes, and the corresponding breast motion during sports activities in active women. The system effectively reduces the noise from human wear trials, providing realistic results on bra performance in controlling breast displacement, fit and pressure. This enables advancements in bra designs.

Findings:

The dynamic manikin system is a low-cost, simple and reliable method for obtaining repeatable and objective results on fit, breast motion and contact pressure during exercise and sports activities. It is suitable for industry application and provides scientific and practical guidelines for bra designers to strategically manipulate key design parameters for optimal breast motion control and bra wearing comfort.

Further Research:

Future work will focus on enhancing the dynamic manikin system by including more diverse breast models of different shapes and age groups. This will further improve the system's ability to provide comprehensive and representative data for bra design and evaluation.

Research Dissemination

Category	Contents
Award	• The 48th International Exhibition of Inventions of Geneva, Switzerland, 26–30 April 2023 (Gold Medal) • School Awards for Outstanding Achievement 2024 in Knowledge Transfer: Industry (Team).
Industry Seminars / Exhibitions	• The Future of Intimate Apparel and Activewear, 29 October 2021 • Fashion Tech Salon, NIKE Product Creation Team, June 2021 • Video sharing at soft manikin.mp4
Media Reports	• Support performance of sports bras (專家評審運動內衣對胸部的支撐), *Choice*, Consumer Council, Vol. 525 on 15 July 2020. • Environmental, Social and Governance Report 2024, Top Form Group (Stock Code: 333), p. 19.
Collaborations	• Research contracts with SGS and testimonials • Licensing agreement with Top Form and OLAB, and testimonials

Research Dissemination | 01 Award

The 48th International Exhibition of Inventions of Geneva 2023: A Gold Medal Award

The exhibition is held from 26 to 30 April 2023 at Palexpo. It is an annual event dedicated to inventions to discover all the latest innovations worldwide.


DIPLÔME

inventions Geneva

SALON INTERNATIONAL DES INVENTIONS GENÈVE

Après examen, le jury international a décidé

de remettre à: Dr Kit-lun YICK, Dr Yiu Wan Joanne YIP, Dr Sun Pui NG, Mr Kwok Tung HUI, Dr Pui Ling LI, Mr Sin Hang Matthew LEUNG

pour l'invention: Un système de mannequin souple spécifique au sport pour la conception de soutien-gorge sportifs

MÉDAILLE D'OR GOLD MEDAL GOLDMEDAILLE

Genève, le 28 avril 2023

Le Président du Jury: David Taj

Le Président du Salon: Jean-Luc Vincent

School Awards for Outstanding Achievement 2024 in Knowledge Transfer: Industry (Team)

Knowledge Transfer: Industry (Team)

Prof. Yick Kit-lun, Professor (Team Leader)

Prof. Joanne Yip, Associate Dean and Professor

Dr Shi Qiuqiong, Research Assistant Professor

Research Dissemination | 02 Industry Seminars

Keynote Speech at AiDLab

The dynamic manikin system was introduced to industry partners at the first seminar held at the Laboratory for Artificial Intelligence in Design (AiDLab), with more than 70 industry participants in October 2021. It was also shared online via Fashion Tech Salon 2021, which was organised by PolyU.

By invitation from the product creation director of **NIKE 360 Holding B.V.**, an online seminar of the latest bra research projects, including the dynamic manikin system design, was held in June 2021.

Research Sharing with the Fashion Tech Salon and NIKE Product Creation Team

Research Dissemination | 02 Industry Seminars

Video of Dynamic Manikin System

Research Dissemination | 03 Media Reports

Bra Tests Reports for the Consumer Council and ESG Report 2024, Top Form Group

Laboratory demonstration of the novel dynamic manikin system was offered to representatives of the Consumer Council and various industry partners, including the chairmen of the Hong Kong Intimate Apparel Industries' Association and Top Form Group.

Top Form Group is an international activewear innovator (US$40M revenue).


"2/3 of apparel chief purchasing officers expect digitisation to be the most important capability for suppliers to grow in the year ahead"
The State of Fashion 2023
EMPOWERING QUALITY WITH DIGITAL INNOVATION

ESG Report 2024, Top Form Group, p.19

Bra performance tests and reports for the Consumer Council

消費者委員會 - 版權所有 Copyright reserved – Consumer Council

專家評審運動內衣對胸部的支撐

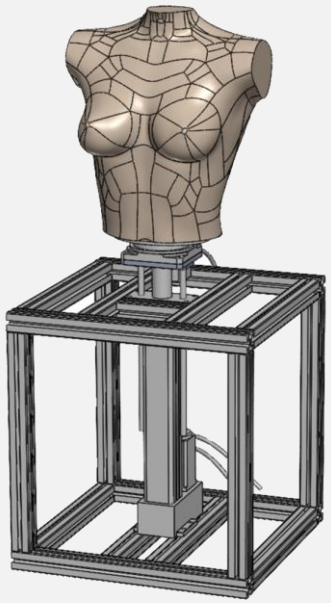
運動內衣的主要功用是在運動時給予胸部足夠的支撐，減少乳房的晃動。有見及此，本會邀請了香港理工大學紡織及服裝學系內衣及運動服裝學副教授易潔倫博士就15款運動內衣進行試用評審。評審以一個上圍為75B的假人模型分別在沒有穿上任何衣物及穿上運動內衣樣本的情況下模擬快速步行，評估各樣本於運動時減低乳房晃動的幅度。各樣本減低晃動的幅度差別不太大，以穿上「lululemon」Energy Bra Long Line (#19)、「H&M」Active Medium Support Push Up Effect Sports Bra (#26) 及「Uniqlo」Women Wireless Bra (Active) (#30) 樣本後乳房晃動的幅度較少。

As invited by the **Consumer Council**, the manikin system was adopted for fit and pressure assessments of sports bras. Related results and bra images are published in the *Choice* magazine, Vol. 525, on 15 July 2020.

Research Dissemination | 04 Contract Research

Two contract research projects on objective evaluation of bra performance with stringent requirements and high quality standard were completed with industry partners, including SGS Testing Service (HK) and GAP Inc.

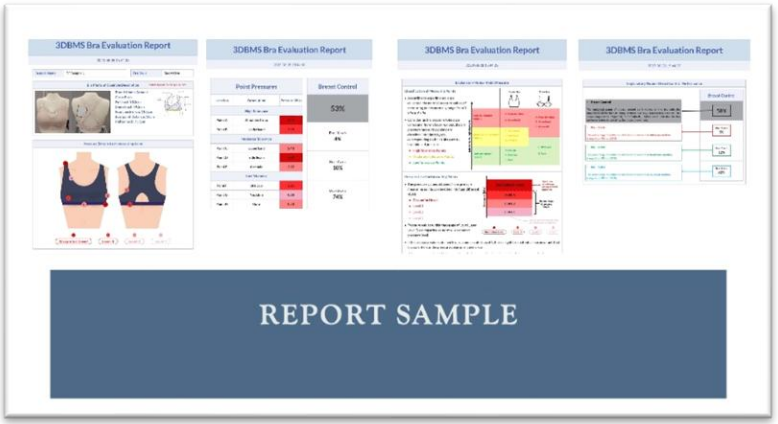
Contract research for Industry and International Testing Services



Bra 1 High support	Bra 2 High support	Bra 3 Medium support	Bra 4 Medium support
			
			

Research Dissemination | 04 Contract Research

SGS is the world's leading testing, inspection and certification company (US$6.2 billion revenue).



SGS

GLOBAL SOFTLINES | HARMONIZATION ACROSS THE GLOBE
WWW.SGS.COM/SOFTLINES

Testimonials

SGS, as a world's leading testing, inspection, and certification company, we are pleased to have had the opportunity to collaborate with Professor Yick on the Soft Manikin project. This research has revolutionized the way for our customer company adopt in bra design and development, providing us with invaluable insights into breast biomechanics in assessing sports bra designs.

This collaboration allowed our customer company to objectively evaluate and improve their bra designs for optimal fit, support, and comfort, enabling them to make necessary adjustments to bra design for different levels of support and sports activities. The project's biomechanical approach has been instrumental in enhancing their product design process. This has not only improved the quality of their products, but also enhanced the well-being of the end-users.

The Soft Manikin project has contributed to our business development. Our customers appreciate the quantitative approach to better understanding the performance of the sports bra designs, and this has led to their customer loyalty and repeat purchases. Moreover, the project has positioned us as a company that seamlessly blends scientific research and customer well-being with aesthetic design.

Yours faithfully,

Ruth Hon
SGS Global Softlines Technical Director
02-Feb 2024

Research Dissemination | 05 Licensing Agreement

Under the NDA, non-exclusive licensing agreements were signed by industry partners for the further development of the system.

Top Form Group

Testimonials

As a leading company in the bra industry, we are thrilled to have had the opportunity to collaborate with Professor Yick on the Soft Manikin project. This research has revolutionized the way we adopt in bra design and development, providing us with invaluable insights into breast biomechanics in assessing sports bra designs.

This collaboration allowed us to objectively evaluate and improve our bra designs for optimal fit, support, and comfort, enabling us to make necessary adjustments to bra design for different levels of support and sports activities. The project's biomechanical approach has been instrumental in enhancing our product design process. This has not only improved the quality of our products, but also enhanced the well-being of our end-users.

It is exciting that the Soft Manikin project has significantly contributed to our business growth. Our customers appreciate the quantitative approach to better understanding the performance of our sports bra designs, and this has led to increased customer loyalty and repeat purchases. Moreover, the project has elevated our brand reputation, positioning us as a company that seamlessly blends scientific research and customer well-being with aesthetic design.

Yours faithfully,

14/2/2024

Kenneth Wong
Managing Director

Date/Month/Year

Testimonial from the Top Form Group

The **Top Form Group** is a full-service design and supply chain partner to global brands and retailers, with unparalleled expertise in manufacturing intimate apparel.

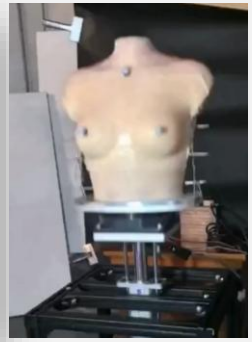
Mr. Kenneth Wong, Managing Director of the Top Form Group stated, '*Thanks to the insights from the dynamic manikin system's test results, we've gained a better understanding of our product performance and design features. Our US customers are impressed and have newfound confidence in our latest product designs and developments!*'

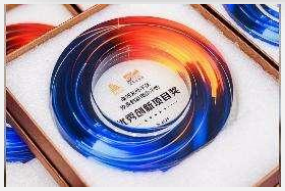
- Annual Corporate Social Responsibility report 2024 of Top Form Group

Research Dissemination | 05 Licensing Agreement

The licensing agreement with **OLAB Co. Ltd**. for adopting the soft manikin system for bra performance evaluation and testing service.

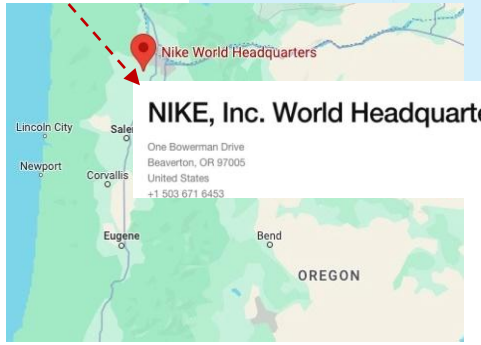
Upgrade version of the soft manikin with bone structure





This upgraded version received the 2024 '**Innovation Anywhere**' Award, presented by the Hong Kong Trade Development Council and the Shanghai Chapter of the Hong Kong Chamber of Commerce.

Collaborations



Appendix I | *Supporting Letters From Industry Partners*

香港內衣業聯會
HKIAIA

28-August 2018

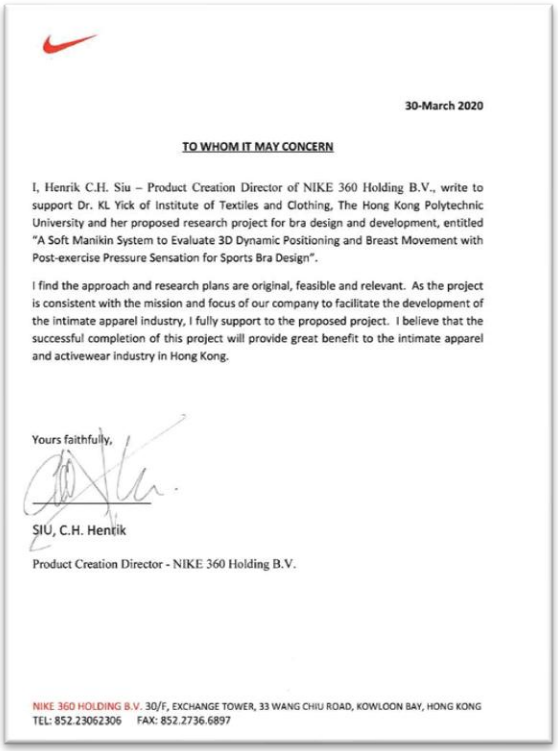
TO WHOM IT MAY CONCERN

On behalf of the Hong Kong Intimate Apparel Industries' Association, we write to support Dr. KL Yick of Institute of Textiles and Clothing, The Hong Kong Polytechnic University and her proposed research project for bra design and development, entitled "A Soft Manikin System for Evaluating Dynamic Breast Movement and Pressure Sensation for Bra Design Optimisation".

We find the approach and research plans are original, feasible and relevant. As the project is consistent with the mission and focus of our association to facilitate the development of the intimate apparel industry, we fully support to the proposed project. We believe that the successful completion of this project will provide great benefit to the intimate apparel industry in Hong Kong.

Yours faithfully,

Hong Kong Intimate Apparel Industries' Association



30-March 2020

TO WHOM IT MAY CONCERN

I, Henrik C.H. Siu – Product Creation Director of NIKE 360 Holding B.V., write to support Dr. KL Yick of Institute of Textiles and Clothing, The Hong Kong Polytechnic University and her proposed research project for bra design and development, entitled "A Soft Manikin System to Evaluate 3D Dynamic Positioning and Breast Movement with Post-exercise Pressure Sensation for Sports Bra Design".

I find the approach and research plans are original, feasible and relevant. As the project is consistent with the mission and focus of our company to facilitate the development of the intimate apparel industry, I fully support to the proposed project. I believe that the successful completion of this project will provide great benefit to the intimate apparel and activewear industry in Hong Kong.

Yours faithfully,

SIU, C.H. Henrik

Product Creation Director - NIKE 360 Holding B.V.

NIKE 360 HOLDING B.V. 30/F, EXCHANGE TOWER, 33 WANG CHIU ROAD, KOWLOON BAY, HONG KONG
TEL: 852.23062306 FAX: 852.2736.6897

27-August 2018

TO WHOM IT MAY CONCERN

On behalf of UA Global Sourcing Limited (subsidiary of Under Armour Inc.), we write to support Dr. KL Yick of Institute of Textiles and Clothing, The Hong Kong Polytechnic University and her proposed research project for bra design and development, entitled "A Soft Manikin System for Evaluating Dynamic Breast Movement and Pressure Sensation for Bra Design Optimisation".

We find the approach and research plans are original, feasible and relevant. As the project is consistent with the mission and focus of our company to facilitate the development of the intimate apparel industry, we fully support to the proposed project. We believe that the successful completion of this project will provide great benefit to the intimate apparel industry in Hong Kong.

Yours faithfully,

Stan Burton
Managing Director, Hong Kong

Appendix II | *Requests for Bra Evaluation From Industry Partners*

From: Siu, Henrik
To: Yick, Kit-lun [ITC]
Subject: RE: <External>Bra evaluations
Date: Tuesday, 6 July 2021 8:01:32 AM

HI Kit,

Thanks for the presentation and the desk shared. Great information for us!
Want to follow up if we can use the soft Manikin for the Intern project? If it's fine, can I ask Hailey and Jessie to connect with you?

Thanks

Henrik Siu | Pcc Director – Bra | DL ☎ (852) 2306 2772 .
NIKE 360 Holding B.V. *(incorporated in Netherlands with limited liability)*
30/Fl., Exchange Tower, 33 Wang Chiu Road, Kowloon Bay, Hong Kong

From: Yick, Kit-lun [ITC] <kit-lun.yick@polyu.edu.hk>
Sent: Monday, June 28, 2021 3:42 PM
To: Siu, Henrik <Henrik.Siu@nike.com>
Subject: <External>Bra evaluations

Dear Henrik,

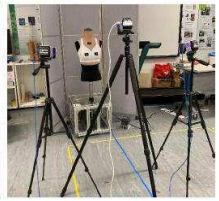
Please kindly find the PPT copy attached.

BR
Kit


Exhale Rib (Size M)


Warrior Longline (Size M)


Phenomena (Size 36B)

Reflective marker locations and setting of cameras

Fok, Queenie (Hong Kong) <Queenie.Fok@sgs.com> Yick, Kit-lun [SFT]; Tong, Fanny (Hong Kong); Sheung, Andy (Hong Kong); Chu, Sammy (Hong Kong); + 1 •
RE: [EXTERNAL] RE: Enquiry about the breast manikin project
You replied to this message on 2/27/2023 9:23 AM.

CAUTION: External email. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Dear Dr. Yick,

Many thanks for arranging the lab visit and introduce the latest manikin to us yesterday. It is our pleasure to visit your lab and it is inspiring and fruitf visit.
We would like to ask for some question about the breast manikin and hand feel project as below.

Brest manikin project

1. May we have the promotion video of latest 3D moving manikin?
2. May we have the price of the service of the 3D moving manikin?
3. May we have the most updated report template?
4. For the report template, could we customize the measuring point?
5. For the report template shown us yesterday, the pressure measurement point is classified as 3 levels of tolerance. May we have more information such as referencing literature, results of your studies etc. about how to define and classify these 3 levels.
6. For the results of pressure, may we know the value of comfortable range in each measuring point? May we have more information such as referencing literature, results of your studies etc. about how to define the mentioned comfortable range.
7. For the calculation of the breast displacement, may we have the equation or formula that how to calculate the displacement control of each plane and the overall displacement control?
8. May we have the information of validation of the manikin? How accurate of the result of pressure and breast control measured from the manikin comparing to human subject? How you perform the validation?

[External]Soft Manikin System for Measuring Vertical Breast Displacement 1

From: Charlotte Murrells <Charlotte_Murrells@gap.com>
Sent: Friday, 18 June 2021 2:04 PM
To: Yick, Kit-lun [ITC] <kit-lun.yick@polyu.edu.hk>
Cc: LI, puiling sabrina [ITC] <puiling-sabrina.li@polyu.edu.hk>; K K Wong <K_K_Wong@gap.com>
Subject: RE: [External]Soft Manikin System for Measuring Vertical Breast Displacement

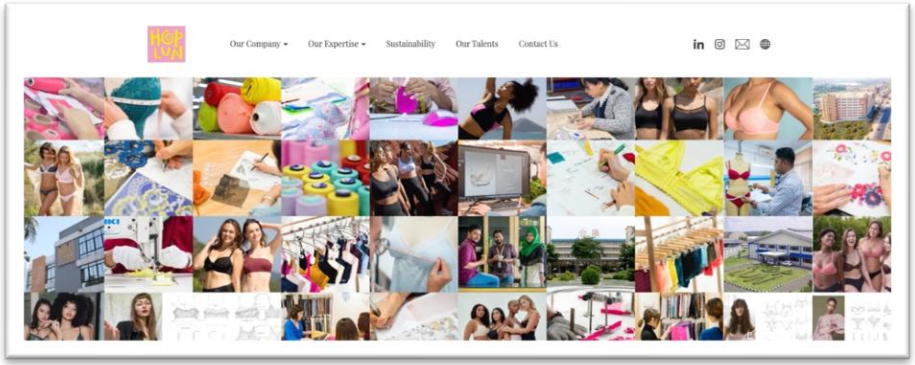
Hi Kit,

As discussed we would like to conduct a trial test on 3 of our sports bras using the current Soft Manikin System to see the potential of the system for our sports bra evaluation.

Best regards
Charlotte

Appendix II | *Requests for Bra Evaluation From Industry Partners*

Hop Lun is a leading global fashion lingerie and swimwear company based in Hong Kong (revenue UD$420M).



From: Allen Wong <allen.wong@hoplun.com>
Sent: Tuesday, February 20, 2024 9:06 PM
To: Yick, Kit-lun [SFT] <kit-lun.yick@polyu.edu.hk>; Angel Lau <angel.lau@hoplun.com>
Subject: Re: Motion Capture test for Sport Bra development

CAUTION: External email. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Dear prof Kit,

OK, I will give you a call tomorrow and have a better understanding. We are asking for motion tests on human subjects because Nike or other big brands use it to test sports bras. My client would like to do similar testing.

We know China has some labs that offer this test on human subjects, but I would like to invest money if HK have this facility.
Is it ok if I set up a call with you at 11:30 am tomorrow??'

Best regards
Allen

MAS Holdings is a global apparel tech conglomerate providing concept-to-delivery solutions for the world's leading apparel brands (revenue US$2billion).

From: Hashini Nimesha <hashinin@masholdings.com>
Sent: Thursday, December 14, 2023 6:42 PM
To: KTEO Info [KTEO] <info.kteo@polyu.edu.hk>
Subject: Soft manikin for dynamic breast movements

CAUTION: External email. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi,

I watched the video about the soft manikin system at A soft manikin system for evaluating dynamic breast movement and pressure sensation for bra design (youtube.com)

A soft manikin system for evaluating dynamic breast movement and pressure sensation for bra design

The soft manikin system, which includes a manikin made of soft silicone and a body movement simulator, mimics the dynamic movements of the soft tissues of hu...

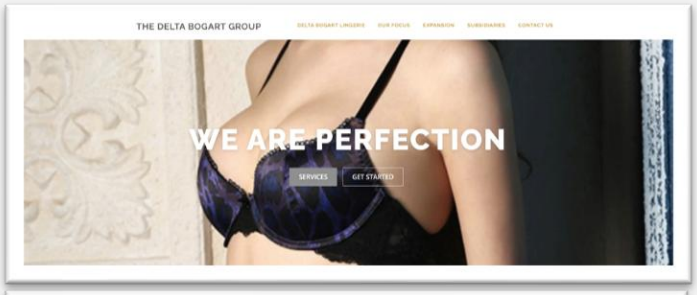
www.youtube.com

I work for an apparel company in Sri Lanka. My team is looking for a soft manikin to test dynamic motion of the breasts. I am looking forward to get more information about this product.

Thanks,
Hashini

Appendix II | *Requests for Bra Evaluation From Industry Partners*

Delta Bogart Lingerie is a top leading name in intimate apparel, sports and swimwear manufacturing, with brands, licences, private label manufacturing and marketing spread in 20 countries (revenue US$46M).



Dear Mr Yick Kit-lun,

I will send the samples as following address, could you pls advise the Tel no.

Attn: Prof. YICK Kit-lun
ST735
School of Fashion and Textiles,
The Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong.

Thank you!

Best Regards,

Mandy Fung
Design Department
DELTA BOGART LINGERIE LTD

A keynote speech invitation from **NIKE** at their first breast symposium in their **head quarters in Oregon, USA**.