# BREASTS BIOMECHANICS; FROM RESEARCH TO ENTERPRISE TO INDUSTRY TO CONSUMER.

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The purpose of this initiative was to use published breast biomechanics methods to develop a bra testing service which steamlined funder engagement, generated income and research data. Following the set up of the Bra Testing Unit (2014), testing packages were sold which establish sports bra performance. To do this, appropriately sized volunteers (n=3,612) were recruited to run bare-breasted and in various sports bras (n=301). Breast movement reduction (% support) and subjective measures, were collected and sports bra support compared across all bras tested. This initiative has streamlined engagement, generated income through 48 package sales to 25 companies worldwide (start-ups to global brands) and is self-sustaining, supporting a biomechanics researcher and offering student opportunities. The data have informed publications; supporting impact case studies. This initiative commercialises, industrialises and consumerises biomechanics research.

**KEYWORDS:** breasts, bras, mastalgia, breast pain, comfort, support

**INTRODUCTION:** Since 2009 the Research Group in Breast Health at Portsmouth University, along with others around the world, have been publishing biomechanical methods that assess the movement of the breast in three dimensions during dynamic activities. These methods have become common place within breast biomechanics research and have been applied to different populations, dynamic activities and breast support products (McGhee and Steele, 2020).

Using these methods to understand the biomechanics of the bare breast provides the bra industry with data on breast support requirements for a given population and dynamic activity. Changes in breast biomechanics when a bra is implemented indicates the effectiveness of the bra at changing bare breasted biomechanics; for example, reducing movement, velocities, accelerations, local deformation, skin strain, breast pain and more. This type of analysis presents the bra industry with an opportunity to assess particular aspects of bra performance.

Unfortunately, no formal industry standard exists to assess sports bra performance. Until such an industry standard exists, the current breast biomechanics methods offer industry comparative bra performance assessment, rather than the validation of product efficacy. Additionally, there is no consensus on the metric that determines appropriate bra performance and this is likely to differ depending on the individual (for example, women suffering from breast pain), the breast size (for example, women with larger breasts may favour support over other metrics), the functional requirements (for example, a sports bra for swimming may be assessed differently to a sports bra for yoga), and more.

Across the breast biomechanics literature, surveys of sports bra preferences rank support and comfort as two of the key metrics which determine an appropriate sports bra (Risius, et al. 2012). Rightly or wrongly, breast support has tended to be established by the percentage of breast movement reduction when exercising wearing a bra compared similar activity in no bra (Scurr, et al. 2010). Breast support categorisation is common in the sports bra market, with brands marketing their products as high, medium and low support (or similar). But without an understanding of what determines appropriate support, it has been difficult for the sports bra industry to objectify these support categorisations (Norris, et al. 2021).

Within breast biomechanics research the assessment of comfort (or discomfort) is often used synonymously with the assessment of pain. It is important to consider the distinction between bra discomfort and breast pain. Comfort can be physical or psychological and is characterised by an unpleasant feeling resulting in avoidance or reduction of the source of the discomfort. Pain is one of the causes for discomfort, but not every discomfort can be attributed to pain (Ashkenazy and Ganz, 2019). Breast pain can exist in multiple forms;

constant, extramammary (occurring elsewhere), movement or menstrual cycle related. Breast pain is a significant issue, effecting half the female population (Scurr et al. 2014), although effective breast support is reported to reduce or even resolve symptoms (Hadi, 2000). Historically, in breast biomechanics research, both variables (bra dis/comfort and breast pain) have been measured subjectively before, during and/or after activity, usually using numeric rating scales, despite the benefits of visual analogue scales.
More recently, for the Research Group in Breast Health at the University of Portsmouth, the methods to assess breast biomechanics were not generating novel research, but were proving beneficial for the bra industry, providing evidence based bra evaluation and comparison. As a result of this the research group established a commercial Bra Testing Unit. The aim of the unit was to utilise published breast biomechanics methods to; streamline engagement with bra industry partners, generate income to support the unit and other breast and bra initiatives within the wider research group, collect a large volume of breast and bra biomechanics data to inform the consumer offering (including support categorisation).

**METHODS:** The University of Portsmouth had no existing testing units and therefore, the first step was the acquisition of standard, ongoing ethical approval, pre-approved costings and standard contractual terms and conditions. A researcher was required to operate the testing unit, the costs of which were initially underpinned by research income, until the unit was self-sustaining. The unit began trading in 2014, after a three year set up period.
Published breast biomechanics methods (Mills, et al., 2016) were used to create three standard bra testing packages (bronze, silver and gold), each offering a similar outcome but incorporating the testing of more bras as the price increased.
Due to the sensitive nature of the data collection, many safeguards were established to protect the volunteers including secure storage of personal and research data, one female only present during testing, familiarisation sessions, confidential participation, and a secure testing environment with no windows.
The unit has a large database of volunteers of varying breast/bra sizes. Volunteers are invited to attend regular laboratory familiarisation sessions, where size is assessed by a trained bra fitter. Volunteers of the required bra size are then invited to the laboratory to take part in testing. Bra size and fit is reassessed with volunteers turned away if they do not fit the bras provided by the industry client. Following an explanation of the procedures, each volunteer completes a breast and bra history questionnaire and height, body mass and bra size are captured. The volunteer then undertakes treadmill running bare breasted and in each bra provided by the client (in a randomised order). Breast biomechanics data is collected using a 6DOF motion sensor system (240 Hz, electromagnetic, Liberty Micro Sensor 1.8, Polhemus, USA; outer diameter, 1.8 mm; mass, 1.0 g), with sensors positioned on the torso and the nipple inside the bra (Norris, et al. 2021). For each volunteer their nipple range of motion is calculated relative to the torso local coordinate system and then as a percentage of the no bra range of motion (Mills, et al. 2016). These data are calculated within a gait cycle and averaged across 10 gait cycles.
Before and/or after each running trial (no bra and in each bra) volunteers complete a questionnaire which assesses bra likes/dislikes, perceived support, bra comfort and breast pain (0=no pain, 10=severe pain). Each bra is tested on twelve women of the same bra size to obtain the following outcome variables (averaged across the group); the percentage of breast movement reduction compared to no bra running, bra comfort, subjective feedback on each bra, severity and location of breast pain, and perceived support. These outcome variables are also compared (anonymously) to all the other bras that have ever been tested by the unit. The amalgamation of breast movement reduction data across this large sample of sports bras (n=301) allows the calculation of tertiles (three categorises), which rank high, medium and low support. Additionally, the researcher also provides subjective feedback and recommendations on each bra based on comparisons with other sports bras.

**RESULTS:** The unit is a not for profit entity; after the first year of trading the unit was self-sustaining, supporting the salary of a researcher and other initiatives within the wider

research group. Forty eight bra testing packages have been sold to 25 companies worldwide (Figure 1); clients range from major global sports apparel brands to small start-ups.


**Figure 1: Location of companies that engaged in biomechanical testing of sports bras.**

Some clients who engaged in bra testing then pursued research collaborations within the wider research group, generating additional income. The unit has tested 301 bras on 3,612 women/cases (bra sizes 34B, 34D, 34E, 36D), reporting breast movement reduction ranging from 36% to 74%. Using tertiles, these data can be grouped into high (≥63% breast movement reduction), medium (≥54% to ≤63%) and low support (<54%) categories, determining the spread of breast support provided across this sample of products (Norris, et al. 2021).

Breast pain data collected following running wearing no bra demonstrated an average pain score of 5.2 out of 10 (standard deviation (SD) 2.8). For each volunteer their lowest breast pain score when running in a sports bra averaged 0.1 (0.4) which was significantly lower than no bra running ($p<0.05$) (Figure 2).

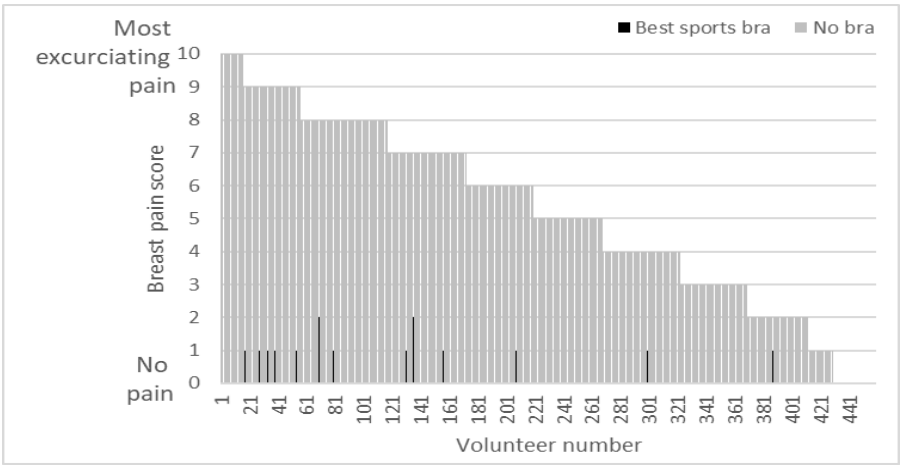


**Figure 2: Breast pain reported by volunteers following running (10 kph) wearing the best sports bra for that individual and wearing no bra (bra sizes 34B, 34D, 34E, 36D).**

Data collected by the unit has informed publications (Norris et al. 2021) and supported impact case studies. The unit has generated educational opportunities for undergraduate and postgraduate students, plus placement and work experience opportunities. From an industry perspective, this initiative has raised the profile of the research group, with some sports bras now marketed based on their performance during our testing.

**DISCUSSION:** The aim of the Bra Testing Unit was to utilise standard breast biomechanics testing methods to offer a sports bra testing service that streamlined engagement with industry partners, generated income and collected a large volume of breast and bra

biomechanics data to inform the consumer offering. Setting up a commercial unit within an academic institution was and still is challenging, but processes have been streamlined making funder engagement quicker and easier, reducing the administrative burden and reducing funder drop out. Enough income has been generated to fund a post for six years, facilitating an early career researcher in biomechanics and also funding other initiatives within the wider research group. A large volume of breast and bra biomechanics data has been collected and used to inform bra development, consumer communication and research in the area. The unit has tried to offer biomechanics data in a user friendly manner for the bra industry and the bra consumer. This activity has demonstrated worldwide reach, with many clients returning for multiple testing services.

With the absence of a sports bra industry standard, current breast biomechanics methods have demonstrated value and impact to the bra industry. However, these methods only enable comparison of sports bra support, rather than absolute performance. Fundamental research is needed to establish a breast support threshold, a criteria for a garment to be called a sports bra. Despite this, an understanding of how much support a particular sports bra provides compared to its competitors has been well received by the bra industry and has enabled a more evidence based approach to the categorisation of high, medium and low support. Again, there is some caution required with this method of categorisation, as tertile thresholds will change with every new bra tested, however, the more data, the more stable the model.

Breast biomechanics research also needs to be conscientious in its description and measurement of comfort and pain, both of which offer valuable insights. This paper reports breast pain scores of 5.2 out of 10 during bare breasted running. Clinically, a breast pain score of greater than 4 is considered clinically relevant (Ader and Browne, 1997), suggesting that running bare breasted causes considerable pain. Interestingly, this pain is almost eliminated (0.1 out of 10) when running wearing the most appropriate bra for that individual.

**CONCLUSION:** The unit has achieved its aims of streamline funder engagement, generating income and building a large research database. There were also many unforeseen benefits; sustaining a research post, research outputs, impact case studies, student opportunities, profile raising in the bra industry. From an industry and consumer perspective the unit offers evidence based sports bra testing, categorisation, credibility for marketing claims, and easy to interpret applied biomechanics data. This initiative commercialises, industrialises and consumerises biomechanics research.

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