Institution: University of Portsmouth

Unit of Assessment: 26 Sport and Exercise Sciences, Leisure and Tourism

Title of case study: Improving sports bra design and breast health through biomechanics research.

1. Summary of the impact

In collaboration with major, global apparel companies, fundamental research by Dr Scurr and colleagues has led to the development of new and innovative methods for investigating the biomechanics of the breast during sport and exercise. This research has generated the following global impacts: knowledge transfer to industry that now use these methods to design and validate their products; economic benefit in terms of increased sports bra sales; increased awareness of this important aspect of women's health and the associated benefits of good-fitting and well-designed apparel.

2. Underpinning research

Weak intrinsic support within the breast and upper body allows independent movement of the breasts, particularly during exercise. This breast movement has negative consequences, which include breast pain (reported in up to 72% of exercising females), breast sag (hypothesised to be caused by repeated loading of internal structures), and decrements in sports performance. Despite the positive health benefits associated with exercise, these factors may reduce participation in physical activity. The negative consequences associated with breast movement have contributed to recommendations for external breast support, particularly during physical activity.

Sports bras have evolved from everyday bras, largely without empirical evidence to demonstrate that they meet the functional requirements. Therefore, in 2005 the Research Group in Breast Health (RGBH) at the University of Portsmouth began work on quantifying breast motion and breast support requirements. The group is led by Dr Scurr (Reader in Biomechanics, appointed 2001), with contributions from Drs White (Senior Lecturer, appointed 2011) and Mills (Principal Lecturer, appointed 2008), and supported by two Senior Research Associates and two PhD researchers.

The RGBH were the first to establish a valid and reliable method to analyse breast movement in three dimensions [1]. This novel method enabled the quantification of breast support requirements determined from the magnitude and direction of breast movement during various sporting activities [2]: these data provided criteria against which the effectiveness of breast support products could be assessed [3]. These research methodologies have now been adopted by the worldwide apparel industry and collaboratively we have developed a unique database of breast support requirements.

Our collaborative research with industry (including the three largest sports apparel companies in the world [text removed for publication]) looks to optimise breast support and thus reduce the negative consequences associated with breast movement. For example, we have undertaken fundamental research on mechanical factors that relate to breast pain, along with applied studies investigating the prevalence, impact and severity of breast pain in sporting populations. This work includes a recent study of 1285 marathon runners that identified that a third of runners experienced breast pain which influenced their adherence to training [4]. To understand the risk of premature breast sag our research is currently considering the potential of repeated loading to cause acute changes to the internal breast structures.

As well as investigating the negative consequences of breast movement our research also considers factors that may influence breast movement, including breast size and anthropometric characteristics [5,6]. All of these research outputs inform breast support optimisation leading to more appropriate products and an increased range of solutions for the end-user.

3. References to the research

1. Scurr, J., White, J. and Hedger, W. (2009). Breast displacement in three dimensions during the walking and running gait cycle. *Journal of Applied Biomechanics.* 25(4), 322-329.
   DOI: [PDF] from scnu.edu.cn
   Impact Factor: 0.8. Citations: 17
   This is the lead journal in the application of biomechanics. This was the first paper to present a method to evaluate the biomechanics of the breast in three dimensions during dynamics activity.

2. Scurr, J., White, J. and Hedger, W. (2010). The effect of breast support on the kinematics of the breast during the running gait cycle. *Journal of Sports Sciences.* 28(10), 1103-1109.
   DOI: 10.1080/02640414.2010.497542
   Impact Factor: 2.1. Citations: 11
   This is a lead journal in sports science in the UK, and this paper was the first to utilise the 3D methodology developments to assess the effects of breast support on breast biomechanics. This paper provided an evaluation method against which sports bra performance could be investigated.

3. Scurr, J., White, J. and Hedger, W. (2010). Supported and unsupported breast displacement in three-dimensions during treadmill activity. *Journal of Sports Sciences*. 29(1), 55-61.
   DOI: 10.1080/02640414.2010.521944 Ref2 output: 26-JW-001
   Impact Factor: 2.1. Citations: 11
   Again in the lead generic sports science journal in the UK, this paper was the first to consider the effects of varying exercise conditions on breast support requirements.

4. Brown, N., White, J., Brasher, A. and Scurr, J. (2013). The experience of breast pain (mastalgia) in female runners of the 2012 London Marathon and its effect on exercise behaviour. *British Journal of Sports Medicine.*
   DOI: 10.1136/bjsports-2013-092175 Ref2 output: 26-JS-001
   Impact Factor: 3.7. Citations: 0
   With an impact factor in the top 10 for sports science/medicine journals, this was a land mark paper providing evidence on the prevalence of breast pain within the exercising population.

5. Wood, L., White, J., Milligan, A., Ayres, B., Hedger, W., and Scurr, J. (2012). Predictors of three dimensional breast kinematics during bare-breasted running. *Medicine and Science in Sport and Exercise.* 44 (7), 1351-1357.
   DOI: 10.1249/MSS.0b013e31824bd62c Ref2 output: 26-JS-003
   Impact Factor: 3.7. Citations: 1
   Again with an impact factor in the top 10 for sports science journals, this paper provided the first evidence on the relationships between breast size and breast biomechanics. These results informed our methods by enabling the scaling of breast biomechanics data.

6. Brown, N., White, J., Milligan, A., Risius, D., Ayres, B., Hedger, W. and Scurr, J. (2012). The relationship between breast size and anthropometric characteristics. *American Journal of Human Biology*. 24 (2), 158-164.
   Ref2 output: 26-JS-004
   Impact Factor: 2.3. Citations: 5
   We targeted this journal to broaden the reach of our research in the biological press in America. This paper focused specifically on health related research providing clinical recommendations for breast surgery criteria.

Key Research Grants for this work **TOTAL £519,320**;

[details of grants received - text removed for publication]

4. Details of the impact

Our research in breast biomechanics has had economic impact for our global sports apparel and bra industry partners. This is evidenced firstly through knowledge/technology transfer, secondly through improved products and increased sales, and thirdly, via global reach in terms of raising awareness of this under-reported aspect of women's health.

Knowledge/technology transfer:
The development of methodologies to measure breast support requirements in three dimensions provided the bra industry with an assessment tool against which product performance could be measured. These methods have been adopted worldwide by the sports apparel industry, both independently and in collaboration with us. This is evidenced in letters from collaborators [text changed for publication] stating that our research has informed their internal research and evaluation methods for future products [1,2]. Our methods both inform the design process, and offer a way to validate marketing claims, providing added value to the consumer (evidenced in correspondence from manufactures [3]). Sports bra manufacturers have used our independent research to provide evidence of the effectiveness of their products [2], enabling women to make informed decisions about the appropriateness of different bras. Evidence for our research informing marketing strategies globally is available on product labels, boxes, manufacturer websites and adverts from some of the largest sporting apparel companies in the world [4].

Improved products and increased sales:
The Sports Bra retailer [text removed for publication] suggest 'the quality of sports bras has increased dramatically with the establishment of a gold standard based on research from the University of Portsmouth', and that our research 'has been instrumental in changing the nature of the sports bra market in the UK' which is reflected in changes in consumer behaviour, 'buyers now ask for research data for new products entering the UK market and increasingly products which have not undergone research are less likely to succeed than those that have' [5]. This has led to increased sales and higher prices, both for manufacturers who have worked with us and for the industry in general. [text removed for publication] [6, 7, 8],

Retailers as well as manufacturers have realised economic benefits through association with our research. Sports bra retailers face a number of challenges; lack of consumer understanding of the product and fit means women often purchase inappropriate garments in inappropriate sizes. Consequently, RGBH established an evidence based Breast Science Workshop which has been delivered in general public forums, industry workshops [text removed for publication] and this workshop programme is due to be rolled out to schools in the UK. A recent RGBH workshop programme for the UK's leading running retailer [text removed for publication], resulted in an increase in sports bra sales and a substantial economic benefit for the retailer [8].

Raising awareness of breast support issues globally
The RGBH has engaged in awareness and educational activities which include press coverage to over 60 million people worldwide, public presentations (Women's Institute, Nuffield Health, MODA, All Woman Show), and television programmes (Channel 4 Sex Education Show, ITV This Morning). The impact of these activities includes social benefits, evidenced in letters from women around the world thanking us for our research, stating that it has 'changed my life' [9], and knowledge dissemination, such as the Channel 4 Sex Education Show, where following our breast health workshop one schoolgirl stated 'this workshop has definitely helped me understand my breasts and showed me the importance of breast support' [10]. This global reach has been instrumental in the expansion of the sports bra market [5] and the increased sales seen by our collaborators.

5. Sources to corroborate the impact

[text removed for publication]