BREAST SUPPORT PERFORMANCE DURING SHORT AND PROLONGED RUNNING

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Recommendations for breast support, dynamic breast pain assessment, and implications on sports performance have been made within breast biomechanics research; however, these have been based upon short exercise protocols (2 to 5 minutes). The aim of this study was to determine the effect of breast support on multiplanar breast displacement and bra performance during short and prolonged running. Significant increases in the mulitplanar breast displacement and a significant decline in the low and high breast support performance were reported from the start to the end of the five kilometre run. Based upon this study, breast biomechanics research and sports bra manufacturers should consider the duration of exercise and product validation protocols, to ensure accurate representation of product capabilities.

KEYWORDS: RUNNING, FEMALES, BREAST SUPPORT

INTRODUCTION: The majority of literature investigating dynamic breast biomechanics has been conducted during treadmill running (Mason, Page, & Fallon, 1999; McGhee, Steele, & Power, 2007; Scurr, White, & Hedger, 2010). Important research questions are examined in these publications, such as establishing the components of effective breast supports, which informs product design (Starr et al., 2005), the assessment of breast pain, ensuring females are exercising in comfort (Scurr, et al., 2010), and examining functional alterations during running to examine the effect of breast kinematics on sports performance (Boschma, Smith, & Lawson, 1995; White, Scurr, & Smith, 2009). Based upon the reported reductions in relative breast kinematics (Mason et al., 1999), improvements in breast comfort (McGhee et al., 2007; Scurr et al., 2010), and the potential to widen exercise participation (Mason et al., 1999), sports bra are recommended as the most appropriate breast support for exercising females. However, these publications have been conducted over short exercise durations, and the potential changes that may occur during longer duration exercise have yet to be considered.

To date, one publication has reported changes in breast displacement over time during a five minute treadmill run. Bowles and Steele (2003) reported significant increases in vertical breast displacement from the first minute to the fifth minute of running. It was hypothesised that this finding was a result of repeated loading on the supportive tissues within the breast. Based upon this hypothesis, it may reasonable to assume that further increases in breast displacement may be reported during prolonged running. In order to examine the effectiveness of breast supports during prolonged running and to improve the external validity of results within breast biomechanics, research should examine breast biomechanics over more common running distances. The aim of this study was to determine the effect of breast support on multiplanar breast displacement and bra performance during a five kilometre run. Firstly, it was hypothesised that increasing the breast support from low to high would reduce the magnitude of multiplanar breast displacement at each interval of the five kilometre run. Secondly, the magnitude of multiplanar relative breast displacement will significantly increase from the start to the end of the five kilometre run. Finally, due to this increase, the performance (percentage reduction of breast displacement) of a low and high breast support will significantly decrease from the start to the end of the five kilometre run.

METHODS: Following institutional ethics approval, ten female volunteers (experienced treadmill and outdoor runners currently training ≥ 30 min, ≥ five times per week) with a mean (SD) age of 23 years (2 years), body mass 62.1 kg (5.4 kg), and height 1.6 m (0.5 m), and a bra size of either 34D or 32DD, participated in this study. Participants performed two five kilometre treadmill runs (average speed 9 ± 1 $km \cdot h^{-1}$) on separate days, once in a low breast support and once in a high breast support. Participants performed an additional two minute barebreasted treadmill run at the same speed as the five kilometre runs. Six retro-reflective hemi-spherical markers (diameter of 12 mm) were positioned on the following anatomical landmarks; the suprasternal notch, the left and right anterior inferior aspect of the 10th ribs, the right nipple (Figure 1) and one positioned on the left heel to identify gait cycles (Scurr et al., 2010). During the two bra conditions, participants repositioned the markers on the bra, directly over the nipple (White et al., 2009).

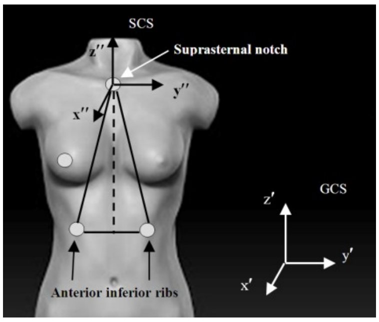

Figure 1. Marker locations, axes and coordinate systems for the global coordinate system (GCS) (x', y', z') and segment coordinate system (SCS) (x'', y'', z'').

Three-dimensional coordinates of the six markers were tracked by eight calibrated Oqus cameras (Qualisys, Sweden), sampling at 200 Hz. Cameras recorded the final ten seconds of the first two minutes of running, and for ten seconds within the final 100 m of each kilometre interval (e.g. 1:50 minutes, 900 m, 1900 m, etc.). Multiplanar coordinates of all markers were exported from QTM and filtered at 13 Hz. Multiplanar coordinates of the nipple markers were transformed, and calculated relative to the thorax segment within Visual3D (C-motion). Minima relative positional coordinates were subtracted from maxima coordinates of the right nipple, during each gait cycle (n = 5) (Scurr et al., 2010) to calculate a mean range of motion (ROM) in each direction. Percentage reductions (%) in multiplanar breast displacement in the low and high breast supports were calculated relative to the two minute barebreasted condition. Data were checked for normality and found to be parametric. One-way repeated measures ANOVAs assessed any differences in multiplanar breast displacement between the three breast support conditions (barebreasted, low and high) during two minutes of running. Two-way repeated measures ANOVAs assessed any differences in multiplanar breast displacement within and between the two breast supports (high and low) across the five kilometre run (six intervals). A one-way repeated measures ANOVA assessed the differences in percentage reductions of multiplanar breast displacement across the five kilometre run (six intervals), within the low and high breast support conditions.

RESULTS: The magnitude of multiplanar breast displacement was significantly different between the three breast supports during the two minute and five kilometre run. The smallest magnitude of multiplanar breast displacement was reported in the high breast support (Tables 1 to 3). When averaged across the five kilometre intervals, the high breast support further reduced the anteroposterior, mediolateral, and vertical breast displacement reported in the low breast support by 14%, 18%, and 31%, respectively.
Increases in mulitplanar breast displacement were seen within the low and high breast support conditions from the start to the end of the five kilometre run. When wearing the high breast support the anteroposterior, mediolateral, and vertical breast displacement increased by 15%, 19%, and 22%, respectively, between the first two minutes and the fifth kilometre interval. In the low breast support, a 17% increase was reported in the vertical direction between the two minutes to the fifth kilometre. The percentage reduction in mutliplanar breast displacement significantly decreased in the low and high breast support from the start

to the end of five kilometre run. For example, the percentage reduction in vertical breast displacement provided by the high breast support during two minutes of running was 67%, however, at the fifth kilometre the percentage reduction is 57% (Table 3).

DISCUSSION: This is the first study to quantify multiplanar breast displacement and breast support performance during short and prolonged treadmill running. Recommendations to wear high breast support for running remain unchanged between short and prolonged running bouts, with the high breast support providing superior support to the breasts when compared to the low breast support across each interval of the run. These findings support previous publications in the area and the first hypothesis.

The increases in multiplanar breast kinematics from the initial two minutes to the final kilometre intervals of the run have implications for previous breast biomechanics publications, which have proposed recommendations for external breast support requirements based upon data collected over shorter run durations (two to five minutes) (Mason et al., 1999; Scurr et al., 2010; 2011; Starr et al., 2005). In line with Bowles and Steele (2003), gradual increases in vertical breast displacement were reported throughout the five kilometre treadmill run in a low breast support condition. Bowles and Steele (2003) attributed these increases to strain on the anatomical supporting tissues of the breast due to the reduced external support provided in this condition, and the cyclic loading on the supportive tissues during running. However, within the current study significant increases in vertical breast displacement were also reported when participants ran in the high breast support. This is an interesting finding when considering the superior support provided within this condition. One explanation for this is the potential bra movement or slippage over the skin during the run, which could be examined in future studies. These results enable the second hypothesis to be accepted.

The percentage reduction in breast kinematics in the low and high breast supports were significantly reduced as the runner progressed through the five kilometre run. The low and high breast supports were up to 19% and 10% less effective at reducing mulitplanar breast displacement at the end of a five kilometre run compared to the first two minutes of running. These data enable hypothesis three to be accepted. With the greatest decline in performance reported in the vertical direction, it is recommended that greater stiffness be incorporated to the vertical components of sports bras, including the shoulder straps. One explanation for the reported increase in multiplanar breast displacement, and the decline in the effectiveness of the two breast supports that should be considered during product validation, is the performance of the material properties of the bras. As the performer progresses through the run, body temperature and sweat rates are likely to increase. Sweat absorbed within the bra (Ayres, White, Hedger, & Scurr, 2013) may influence the mechanical properties of the bra materials, such as elasticity, stretch ability, recovery and strength.

Table 1. Mean (SD) anteroposterior breast displacement (mm) in three breast support conditions and percentage reductions (Red. %) at each interval of the five kilometre runs.

INTERVAL	BB	LOW	RED. %	HIGH	RED. %
2 MINS	41 (5)[ab]	34 (3)[c]	16%	24 (6)[c]	42%
1 KM	N/A	36 (3)[c]	11%	27 (6)[c†]	33%*
2 KM		38 (4)[c]	6%	27 (6)[c]	33%*
3 KM		38 (5)[c]	6%	27 (5)[c]	31%*
4 KM		37 (5)[c]	9%	27 (6)[c]	34%*

5 KM		37 (6)^{c}	9%	28 (6)^{c†}	32%*

Table 2. Mean (SD) mediolateral breast displacement (mm) in three breast support conditions and percentage reductions at each interval of the five kilometre runs.

INTERVAL	BB	LOW	RED. %	HIGH	RED. %
2 MINS	50 (11)^{ab}	36 (7)^{c}	26%	26 (5)^{c}	46%
1 KM		38 (6)^{c}	21%*	30 (5)^{c}	39%*
2 KM		40 (8)^{c}	17%*	31 (7)^{c}	37%*
3 KM	N/A	40 (7)^{c}	18%*	32 (7)^{c}	35%*
4 KM		40 (8)^{c}	19%*	32 (6)^{c†}	35%*
5 KM		40 (9)^{c}	21%*	32 (5)^{c†}	37%*

Table 3. Mean (SD) vertical breast displacement (mm) in three breast support conditions and percentage reductions at each interval of the five kilometre runs.

INTERVAL	BB	LOW	RED. %	HIGH	RED. %
2 MINS	60 (13)^{ab}	34 (9)^{c}	37%	18 (4)^{c}	67%
1 KM		38 (9)^{c†}	29%*	21 (6)^{c}	60%*
2 KM		39 (9)^{c}	28%	22 (5)^{c†}	58%*
3 KM	N/A	40 (8)^{c}	26%*	22 (5)^{c†}	58%*
4 KM		40 (8)^{c†}	25%*	22 (5)^{c†}	58%*
5 KM		41 (8)^{c†}	23%*	23 (6)^{c†}	57%*

BB = Barebreasted condition

[a]Significant difference between the BB and low breast support conditions, $P < 0.05$
[b]Significant difference between the BB and high breast support conditions, $P < 0.05$
[c]Significant difference between the low and high breast support conditions, $P < 0.05$
†Significant increase from the first two minutes and the distance intervals, $P < 0.05$
*Significant difference in Red.% from the first two minutes and the distance intervals, $P < 0.05$

CONCLUSION: The current study has demonstrated that a high breast support provides superior support during short and prolonged running, and multiplanar breast displacement significantly increased over a five kilometre run in both low and high breast support condition. The increase in multiplanar breast displacement during the five kilometre run was associated with a significant deterioration in the performance of the two breast supports. The implications these findings may have for long-distant female runners is important, and indicate that the breast support provided at the start of a run will not be maintained over a five kilometre run. With breast displacement reported to significantly increase from as early as the first kilometre of a five kilometre run, it is recommended that breast biomechanics research carefully consider the exercise duration examined, and assess the performance of a sports bra over typical running distances.

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