BREAST MOVEMENT ASYMMETRY DURING RUNNING: IMPLICATIONS ON BREAST SUPPORT

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This study aimed to investigate 1) the prevalence and magnitude of breast movement asymmetry, 2) the interaction between static and dynamic breast asymmetry during running and 3) the influence of sports bras on breast asymmetry. Nipple position data were collected from 167 female participants whilst treadmill running and then from a sub-group of twelve participants running in different bra conditions. Breast movement asymmetry was present in 74% of participant during running, with greater resultant static breast position asymmetry for participants that displayed asymmetry whilst running. Asymmetry was most commonly caused (65 - 80%) by greater movement of the left than right breast. Sports bras reduced asymmetry prevalence to as few as 17% of participants in the antero-posterior direction but only 58% in the infero-superior direction.

KEYWORDS: Breast Health, Garment Design, Running Gait, Kinematics

INTRODUCTION: Breast asymmetry relating to mass and shape of the breast has been reported to exist in up to 94% (Losken, Fishman, Denson, Moyer & Carlson, 2005) of the female population. This breast asymmetry has been reported to show both positive (Losken et al., 2005) and negative (Manning, Scutt, Whitehouse & Leinster, 1997) relationships with overall breast size. Breast asymmetry has clear implications on breast support requirements, which may differ for left and right sides due to potential asymmetry in the mass and consequently force applied by each breast. Asymmetry within the human body has also been widely reported relating to limb length and performance measures in gait (Perttunen, Anttila, Södergård, Merikanto & Komi, 2004). Previous work has shown that biomechanical asymmetry in gait can be individualistic in nature (Exell, Irwin, Gittoes & Kerwin, 2017).
The importance of correctly fitting and appropriate breast support garments during running has been reported in the literature (Mason, Page & Fallon, 1999; White, Mills, Ball & Scurr, 2015). However, asymmetry within individuals' breast movement during running, may alter the support and fit needed for each breast. Therefore, information relating asymmetry in breast movement with other predictive factors such as breast size or static asymmetry could be beneficial in informing breast support requirements. The presence of breast movement asymmetry is inconclusive having been reported during running (Mills, Risius & Scurr, 2015) but not when measured statically (Chen et al., 2013). Furthermore, relationships between breast asymmetry when measured statically and during dynamic activities or between breast movement asymmetry during running and breast size are not well known.
The aims of this study were to investigate 1) the prevalence and magnitude of kinematic breast asymmetry during running, 2) the interaction between static and dynamic breast asymmetry and 3) the influence of different sports bras on breast asymmetry during running. The purpose of the study was to advance understanding of breast asymmetry and to inform bra manufacturers, athletes and researchers about the incidence of breast movement asymmetry. It was hypothesised that significant breast movement asymmetry would exist during running (H1), that it would be positively related with static breast asymmetry (H2) and bra size (H3) and that a sports bra would reduce breast movement asymmetry (H4).

METHODS: Ethical approval was gained from the University Research Ethics Committee. All participants provided informed consent prior to data being collected. Two separate protocols were utilised to address the study's research questions. Collection A involved a descriptive analysis of asymmetry prevalence. Collection B incorporated an intervention of varying sports bras to assess the influence of support on breast movement asymmetry (H4). Exclusion criteria for both collections included previous breast surgery and being pregnant.

Collection A: Position and bra size data were collected from 167 female participants (25 ± 5 years, 63.3 ± 7.4 kg, 1.66 ± 0.06 m, bra size 32A - 34G) stored in a database. Cross-graded bra size was assessed by a trained bra fitter. Breast and torso position data were measured (Oqus, Qualisys ® Sweden) at a minimum of 100 Hz. Reflective markers were positioned on participants' suprasternal notch, left and right anterior inferior aspect of the 10th ribs and on left and right nipples to track breast motion (Scurr, White & Hedger, 2011). Participants ran on a treadmill (H/P/Cosmos Mercury, Germany) at a treadmill speed of 2.78 m/s whilst bare-breasted. Data were collected for five complete strides (i.e. ten steps).
Data were reconstructed (QTM Versions 1.10 - 2.13, Qualisys, Sweden) and position data filtered using a second-order low-pass Butterworth filter (cut-off 13 Hz). Nipple position was calculated relative to the trunk coordinate system (Mills et al., 2015). Range of motion (ROM) of each nipple marker was quantified and asymmetry of ROM was then quantified using the modified symmetry angle to define significant asymmetry (Exell, Gittoes, Irwin & Kerwin, 2012). The number of participants demonstrating significant dynamic asymmetry was calculated as the percentage of all 167 participants. For participants displaying significant asymmetry, the relationship between breast size and asymmetry was investigated via the Spearman correlation coefficient. Static symmetry angle magnitude (Exell et al., 2012), based on nipple to sternal notch separation, was compared in each direction between participants that displayed significant dynamic asymmetry and those that did not, using independent t-tests with Bonferroni correction. Effect sizes were quantified for this comparison using the method and classification outlined by Cohen (2013).
Collection B: Twelve participants that were a 34D bra size were randomly selected for further analysis (25 ± 5 years, 64.8 ± 6.2 kg, 1.68 ± 0.05 m). Position data were collected at 240 Hz using an electromagnetic motion tracking system (Micro Sensor 1.8TM, Polhemus, Colchester, Vermont, USA) allowing sensor motion to be tracked underneath the bra material. Six sensors were placed on the: suprasternal notch, xiphoid process, seventh cervical (C7) and eighth thoracic (T8) vertebrae and on left and right nipples. Each participant then ran on a treadmill (H/P/Cosmos Mercury, Germany) at 2.78 m/s during four different bra conditions. During each bra condition, participants were asked to run for a time of 2 minutes, following which, data were collected for ten complete strides (i.e. twenty steps). The conditions tested were: 1. Bare breasted. 2. A high support sports bra with adjustable underband and straps in a cross-back strap configuration and encapsulating cup support (Bra 1). 3. A medium support sports bra without adjustable straps or underband, racer back strap configuration and compression style support (Bra 2). 4. A high support sports bra with an adjustable underband only, racer back strap configuration and encapsulating cup support (Bra 3). For Conditions 2-4 sports bras were fitted and adjusted to each participant.
Nipple position data relative to the trunk were filtered, as in Collection A. The trunk segment was defined based on ISB recommendations (Wu, van der Helm, Veeger, et al., 2005). Asymmetry significance was quantified as in Collection A. Asymmetry prevalence was calculated during each bra condition.

RESULTS:

Collection A: 124 participants (74%) demonstrated significant dynamic breast asymmetry in at least one direction (Table 1). More than half of the participants displayed significant asymmetry in breast ROM for at least one direction with most occurrences of asymmetry occurring in the infero-superior direction. Table 1 also includes results for the direction of asymmetry, which showed that a larger ROM most often occurred in the left breast. Differences in bra size between asymmetrical and non-asymmetrical participants were small with the largest difference being 0.13 cross grade magnitudes for the antero-posterior direction, whilst all other differences were $\leq$ 0.06. Relationships between dynamic asymmetry magnitude and breast size are also presented in Table 1 for participants that displayed significant asymmetry. The largest correlation magnitude was 0.24, indicating that only 6% of asymmetry magnitude was explained by bra size.

Table 1: Number of participants displaying significant asymmetry, direction of asymmetry for ROM (values in brackets are associated percentages) and correlation with breast size during dynamic trials.

	Direction			
	Antero-posterior	Medio-lateral	Infero-superior	resultant
Significant asymmetry	60 (36%)	60 (36%)	80 (47%)	53 (31%)
Direction (L>R)	48 (80%)	40 (67%)	52 (65%)	36 (68%)
Correlation (ρ) with breast size	0.11	-0.24	0.07	-0.12

Static nipple position asymmetry magnitude is presented in Table 2, comparing static asymmetry for asymmetry groups during the dynamic trials. Static asymmetry was only significantly different between dynamic asymmetry groups in the resultant direction (Table 2).

Table 2. Static asymmetry magnitude for participants that displayed significant asymmetry during running trials (A) and those that did not (NA). ES = effect size. SD = standard deviation.

	Direction							
	Antero-posterior		Medio-lateral		Infero-superior		resultant	
	A	NA	A	NA	A	NA	A	NA
Mean	6.62	5.75	3.57	3.04	1.35	1.42	1.43	0.89
(±SD)	(6.21)	(4.36)	(2.72)	(2.66)	(1.27)	(1.05)	(1.22)	(0.64)
ES	0.16		0.20		0.06		0.55*	

* = significant difference between static asymmetry magnitude for asymmetrical (A) and non-asymmetrical (NA) groups during dynamic running.

Collection B: Table 3 includes the number of 34D sub-group participants displaying significant ROM asymmetry for each bra condition. Asymmetry was prevalent in all directions, with the greatest number of participants displaying significant asymmetry in the infero-superior direction and the least in the antero-posterior direction. The largest asymmetry prevalence across all directions was displayed in the no bra condition, followed by the Bra 2. Bra 1 reduced the number of participants displaying significant asymmetry the most, eliminating significant asymmetry for all but two participants in the antero-posterior direction and seven participants in the infero-superior direction.

Table 3. Number of 34D group participants, displaying significant asymmetry in each direction during different bra conditions (values in brackets are associated percentages).

	Direction			
	Antero-posterior	Medio-lateral	Infero-superior	resultant
No Bra	7 (58%)	8 (66%)	9 (75%)	8 (66%)
Bra 1	2 (17%)	5 (42%)	7 (58%)	6 (50%)
Bra 2	7 (58%)	7 (58%)	8 (66%)	8 (66%)
Bra 3	4 (33%)	7 (58%)	8 (66%)	6 (50%)

DISCUSSION: The aims of this study were to investigate 1) the prevalence and magnitude of kinematic breast asymmetry, 2) the interaction between static and dynamic breast asymmetry and 3) the influence of different sports bras on breast asymmetry during running. Results demonstrate that asymmetry of breast movement was present in one or more direction in almost three quarters of the 167 women tested during running, therefore accepting H1. The most prevalent direction of breast movement asymmetry was the infero-superior direction, with almost half (47%) of the participants demonstrating this. These results support the finding of asymmetry in breast movement reported by Mills et al. (2015).

The high prevalence of breast movement asymmetry indicates that it is important to consider side-specific support requirements in bra fitting (White et al., 2015) and design. It is suggested that support should minimise movement of the side that shows larger movement

during dynamic activity. In this study, the side demonstrating greater movement was most often the left side, which may be due to the left breast tending to be larger, as reported in previous research (Losken et al., 2005). However, not all participants demonstrated greater movement on the left side, highlighting the individual basis of breast asymmetry.
Static breast asymmetry did not significantly differ between asymmetrical and non-asymmetrical participants during the dynamic activity when considering component positions. However, in the resultant direction, a significant difference (with medium effect size) in static asymmetry was reported; therefore, H2 was partially accepted. No meaningful relationship was found between asymmetry and breast size, rejecting H3. These findings conflict with previous research that has reported greater asymmetry in smaller breasts (Manning et al., 1997). Based on these results, it is recommended that, if it is not possible to include dynamic activity when fitting or assessing sports bras, the difference in resultant magnitude of the nipple to sternal notch separation is used to indicate breast asymmetry. Sports bras tended to reduce asymmetry prevalence and magnitude; therefore, H4 was accepted.

CONCLUSION: The largest reduction in asymmetry prevalence was consistently achieved by Bra 1, which suggests that the inclusion of adjustable straps and an adjustable underband is an important factor allowing breast support to be customised for each breast to reduced asymmetry of breast movement. From a data collection perspective, the high number of participants demonstrating asymmetry of breast movement in at least one direction highlights the importance of collecting bilateral data when investigating breast movement.
These findings may have implications for both sports bra design and future breast research data collection protocols. When considering the practical applications and differing breast support requirements between sides, it is suggested that manufacturers consider how bras can allow customisable support between sides, such as by adding size or tension control to each cup independently and customising the elastic properties of each strap.

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