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BREAST SUPPORT IMPLICATIONS FOR FEMALE RECREATIONAL ATHLETES DURING STEADY-STATE RUNNING

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The aim of this study was to investigate the effect of high (HS) and low (LS) breast support on running kinematics and breast comfort during steady-state running. Eleven larger-breasted female recreational athletes completed a short duration treadmill run (2.58 m/s) in a LS and HS condition. Multi-planar breast and running kinematics were analysed; breast comfort was rated at the end of each treadmill run. The HS condition significantly reduced breast kinematics and increased breast comfort. Differences in lower-extremity mechanics were found between breast support conditions; results suggest performance may be compromised if high breast support is not worn. Individual running mechanics were also found to influence breast kinematics, highlighting that some runners may need custom-made breast support.

KEY WORDS: breast, kinematics, running, comfort, performance

INTRODUCTION: Running is a popular activity for female recreational athletes in the UK and research that can aid improvements in this activity may have important implications for those who participate. The majority of research in this area has utilised elite male runners and less attention has been given to female and recreational athlete populations. Biomechanical changes to female athletes' running performance, which allow them to utilise less energy at a given velocity, should be of benefit.

Breast kinematic variables (breast displacement, velocity and acceleration) have been found to significantly reduce, and breast comfort increase, when a sports bra is worn compared to an everyday bra (Mason et al., 1999; Scurr et al., 2010; White et al., 2011). Shivitz (2001) proposed that a female runner may try to alter her running technique if she experiences breast discomfort. Preliminary studies in the area suggest that while group analyses found breast support did not affect running kinematics, large individual changes in some kinematic parameters occurred due to breast support (Boschma, 1994; Shivitz, 2001).

Extreme elbow joint angle, excessive trunk and arm rotation, excessive trunk flexion and extension, a lack of arm movement, excessive vertical oscillation of the body's centre of mass, under- or over-striding and minimal knee flexion or extension at various phases of a stride are variables proposed to be mechanical flaws in running style (Messier & Cirillo, 1989). Although there is limited evidence linking biomechanical parameters to optimal performance in running, a more detailed investigation into the effect of breast support on running performance is warranted.

Research to-date has utilised smaller-breasted women (A to D cup); larger-breasted cohorts should be investigated as they are more likely to experience exercise-related breast discomfort (Lorentzen & Lawson, 1987). The implications of inappropriate breast support on female running performance is unclear, this study aimed to investigate biomechanical and perceptual responses to changes in breast support within a population of larger-breasted female recreational runners.

METHODS: Following institutional ethical approval, eleven larger-breasted (D to E cup size) female recreational runners (mean ± SD: age 26 ± 7 years, height 1.66 ± 0.04 m, body mass 64.32 ± 6.38 kg) were selected. Subsequent to a 5-minute self-paced treadmill warm-up participants put on either a LS (everyday; 88% Polyamide, 22% Elastane Lycra) or a HS (sports; 45% Polyester, 44% Polyamide, 11% Elastane) bra in a random order; participants were bra fitted according to White & Scurr (2012).

For breast kinematic analysis retroreflective markers were placed on the suprasternal notch, left and right anterioinferior aspect of the 10th ribs and the right nipple (on the bra, directly over the nipple) (Scurr et al., 2010). Additional markers were placed on the right side of the participant (acronium process, lateral elbow epicondyle, radius styloid process, greater trochanter, lateral knee epicondyle, lateral malleolus, heel & 5th metatarsalphalangeal joint). This enabled calculation of: stride frequency (strides/min), stride length (m), distance covered per minute (m), maximum swing and stance knee flexion (°), thigh ROM in the sagittal plane (°), vertical thorax displacement (cm) and frequency (Hz), thorax ROM in the sagittal, frontal and transverse planes (°), mean elbow angle (°) and upper arm ROM in the sagittal and frontal planes (°).
Each participant completed a 7 minute 20 s treadmill run at 2.58 m/s in the LS and HS conditions. Multi-planar kinematic data were captured by eight infrared Oqus cameras (200 Hz; Qualysis, Sweden) during the last 30 s of the run. Immediately following each treadmill run breast comfort was rated using a 0 (no pain) to 10 (painful) visual analogue scale (Mason et al., 1999). Markers were identified and reconstructed in Qualysis Track Manager (QTM) software (Qualysis, Sweden) and filtered in MatLab (version 2010a); mean (SD) multi-planar breast kinematics (Scurr et al., 2010) and biomechanical variables were calculated over the same 5 gait cycles at the start of the 30 s data capture. Anterioposterior (a/p) right heel marker velocity data were used to determine footstrike events. Knee flexion/extension angles were calulated by substracting the absolute leg segment angle from the absolute thigh segment angle at each time point. The suprasternal notch was used to represent vertical thorax motion; thigh, thorax and upper arm segment angles were measured with respect to the global vertical or m/l axis (global axes were set up so segments had a neutral position of zero degrees) and a relative angle was calculated at the elbow. Paired samples *t*-tests (SPSS) examined differences between LS and HS conditions (alpha level of 0.05). Pearson or Spearman's correlation coefficents examined relationships between breast kinematics, comfort and biomechanical variables ($r > 0.5$ = moderate relationship; $r > 0.7$ = strong relationship); stepwise regression analyses were utilised for prediction modelling.

RESULTS: Breast displacement (cm) in all directions (Figure 1), vertical and a/p breast velocity (cm/s) and vertical acceleration (*g*) were lower in the HS condition. Breast comfort was consistently high in the HS condition (mode: 0); running in the LS condition was most frequently reported as being between 'uncomfortable' and 'painful' (mode: 7). Significant positive relationships were found between breast kinematics and breast comfort (r_s = 0.55 to 0.79, $p < 0.007$), the strongest correlations were in the a/p direction.

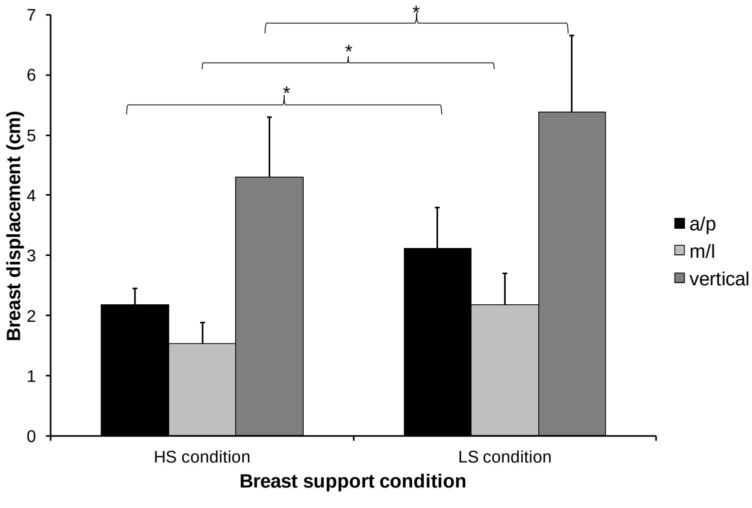

Figure 1: Mean (SD) multi-planar breast displacement in the LS and HS conditions, * = $p < 0.05$

Despite a constant treadmill velocity and no changes in stride frequency between the LS and HS conditions, mean stride length was shorter (0.04 m) and a decreased thigh ROM (0.45°) was present in the LS condition (Table 1), leading to less distance being covered per minute (3.08 m). Maximum swing knee flexion was also lower in the LS condition (1.07°, p = 0.044).

Table 1: Mean (SD) results for biomechanical variables in the LS and HS conditions, *= *p* < 0.05

Biomechanical variable	Mean LS (*SD*)	Mean HS (*SD*)	*p* value
Stride frequency (strides/min)	81.97 (*1.48*)	81.97 (*1.94*)	0.499
Stride length (m)	1.85 (0.05)	1.89 (0.05)	0.002*
Distance covered per minute (m)	151.68 (3.39)	154.76 (0.47)	0.006*
Maximum stance knee flexion (°)	47.80 (1.13)	47.79 (0.98)	0.994
Maximum swing knee flexion (°)	92.65 (1.70)	93.72 (1.90)	0.044*
Thigh ROM in the sagittal plane (°)	47.58 (3.15)	48.03 (3.12)	0.039*
Vertical thorax displacement (cm)	10.01 (0.61)	10.13 (0.87)	0.349
Vertical thorax frequency (Hz)	2.66 (0.06)	2.66 (0.08)	0.613
Thorax ROM in the transverse plane (°)	24.72 (9.32)	25.46 (8.55)	0.082
Thorax ROM in the frontal plane (°)	11.33 (3.37)	10.84 (2.60)	0.383
Thorax ROM in the sagittal plane (°)	13.37 (2.86)	12.16 (2.80)	0.129
Mean elbow angle (°)	71.59 (5.70)	70.32 (6.19)	0.075
Upper arm ROM in the frontal plane (°)	13.96 (3.79)	14.13 (4.82)	0.448
Upper arm ROM in the sagittal plane (°)	68.78 (10.90)	70.44 (9.29)	0.237

Differences found in stride length and the distances covered per minute were supported by relationship testing and prediction modelling. A negative relationship was found between a/p breast displacement and stride length (r_p = -0.644, p = 0.002) and between a/p breast displacement and breast comfort (r_s = -0.629, p = 0.012); a/p breast displacement also acted as a significant predictor of stride length (41%). Mediolateral breast velocity related positively to sagittal plane thorax ROM (r = 0.541, p = 0.037); thorax ROM in the frontal plane related positively to a/p (r = 0.732, p = 0.002) and m/l (r = 0.606, p = 0.017) breast acceleration.

DISCUSSION: The effect of breast support on biomechanical variables and breast comfort during steady-state running were investigated for the first time in this study. The greater reduction in multi-planar breast kinematics when participants in this population of larger-breasted female runners wore a sports bra confirms earlier research (Mason et al., 1999; Scurr et al., 2010; White et al., 2011) and provides rationale for women to wear high breast support when running to reduce excessive breast displacement. The large difference in breast comfort perception between the LS and HS conditions, coupled with changes in breast kinematics, justify an investigation into biomechanical changes in larger-breasted females that may occur in running technique when breast support level is altered.

Contrary to previous research (Boschma, 1994; White et al., 2011), participants ran with a longer stride length in the HS condition; when extrapolated participants covered just over three metres per minute more than in the LS condition. It is proposed that increases in a/p breast displacement and decreases in breast comfort may have led participants to consciously decrease their stride length; participants may have chosen to not ‘stride out’ as far in the LS condition due to greater breast displacement and discomfort experienced. The shortening of stride length in the LS condition could have important performance implications and is a novel finding of this study. These results imply there may be a detriment to performance during steady-state running if inadequate breast support is worn.

Increased knee flexion during the swing phase is anticipated to relate to better running economy by reducing the limb’s moment of inertia and allowing the runner to rotate the limb more quickly and with less effort (Hay, 1978). Knee flexion during swing was greater in the HS condition, suggesting that running with greater breast support may be beneficial for running performance. This result coincides well with the longer stride length and greater thigh ROM in the HS condition.

Although no differences were found in upper-extremity biomechanical variables between the LS and HS conditions, some relationships were found between breast kinematics and thorax ROM. Due to no change in thorax ROM between breast support conditions it is proposed that participants who ran with greater thorax ROM stimulated increases in breast kinematics. If, as the findings suggest, an individual's running style influences breast kinematics then perhaps runners with certain mechanics may require firmer breast support than others. This has implications for the design of sports bras for individual athletes; a sports bra custom-made to an athlete's running mechanics could provide optimum support and comfort.

Anterioposterior breast kinematics were most closely related to breast comfort in this study, contrary to the relationship to vertical breast kinematics reported in previous research (Scurr et al., 2010); a/p breast kinematics also acted as significant predictors, and were most closely related, to stride parameters. This was surprising as most breast displacement occurred in the vertical direction (Figure 1). The exact mechanism of exercise-induced breast discomfort is unknown, thus it is difficult to interpret the complex relationship between a/p breast kinematics and breast comfort, and the subsequent implications for running mechanics in larger-breasted female runners. However, findings suggest that reducing a/p breast displacement could be a high priority for bra design.

CONCLUSION: The HS condition significantly reduced breast kinematics and increased breast comfort compared to the LS condition during steady-state running (2.58 m/s) in larger-breasted female runners. Stride length, distance covered per minute and thigh ROM were lower when participants ran in the LS condition with a decreased knee flexion during the swing phase. These results have important implications for performance when larger-breasted women choose to run without high breast support. An individual's running mechanics may influence the magnitude of breast kinematics; therefore some larger-breasted female runners may need custom-made breast support to reduce excessive breast movement and discomfort. Reducing a/p breast kinematics in particular could be key. The use of a high support bra when running at a steady-state treadmill velocity is recommended based on the findings of this study for improved breast comfort and running performance.

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