Adding an underwire in bras decreases breast motion and discomfort during locomotion

X Chen¹³, X Sheng¹, G Sun¹³, Y Li¹³, M J Lake² and H Xie¹³

¹ School of Textiles and Fashion, Shanghai University of Engineering Science, Shanghai, 201620, P.R. China
² Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, L3 3AF, United Kingdom
³ Textile Industrial Key Lab of Ergonomics and Functional Clothing, Shanghai University of Engineering Science, Shanghai, 201620, P.R. China
⁴ Sino-British Joint Lab for Smart Sportswear, Shanghai University of Engineering Science, P.R. China

Abstract. The aim of this study was to determine whether exercise-induced vertical breast motion and discomfort in women with large breasts decrease when an underwired bra is used compared with when an underwire-free bra is worn. Vertical breast displacement was assessed in nine women (C cup size) who exercised on a treadmill in two bra conditions: underwired bra and underwire-free bra. Perceived breast motion and discomfort were reported by each participant using the visual analogue scale after each bra condition trial. Vertical breast displacement and perceived breast motion and discomfort were compared between the two bra conditions. Vertical breast displacement (p < 0.05) and perceived breast motion (p = 0.007) and discomfort (p = 0.025) were significantly lower in the underwired bra condition than in the underwire-free bra condition. The bra design feature of containing an underwire was effective in decreasing exercise-induced vertical breast motion and discomfort among the women with large breasts. The current research is the first study to explore the effects of including a bra underwire on the change in breast motion and discomfort.

1. Introduction

Many studies have reported that excessive vertical breast displacement during exercise induces breast discomfort, especially for women with large breasts[1-3]. The vertical breast displacement value during walking seems negligible. Nonetheless, a recent article[4] concluded that individuals usually walk 4961 steps per day, which implies 43160.7 mm of accumulated vertical breast displacement per day if we anticipate the vertical breast displacement of women during walking to be 8.7 mm[5]. Furthermore, the same study found that women walked more steps than did men, which indicated that the current measure was likely to underestimate the accumulated vertical breast displacement of women during daily walking. The repeated loading from the accumulated vertical breast displacement may easily induce the stretch of Cooper’s ligaments, which are supposed to be the primary anatomical support structure for breasts, but only provide limited support to the breast region, are easily stretched after repeated loading [1]. Wearing a well-fitted and supportive bra has been considered as an effective method of limiting vertical breast displacement and related breast discomfort[2-3][6-8].
Most investigations on breast motion can be classified into two topics: research on breast biomechanics[5][9-14] and research on the effect of bra design features on breast motion[2][15-21]. To test whether exercise-induced breast discomfort during deep water running could be replicated during land running[22], modifications were made by combining the characteristics of encapsulation and compression within one bra cup[2]. Although this change can reduce exercise-induced breast discomfort, it was not proven to be effective in reducing vertical breast displacement[2]. Similarly, a previous study found that there was no significant difference in exercise-induced breast pain and vertical breast motion between two bra strap orientations (traditional orientation versus crossed back orientation)[18][23]. It is difficult to decrease exercise-induced vertical breast displacement with these changes, especially in bras providing high levels of breast support. Thus, other modifications on bra cups and/or shoulder strap designs or modifications on other parts of bras should be investigated to determine an effective method to limit vertical breast motion.

Usually, a common bra consists of the following parts: cup, straps, band, gore, underwire, cradle, and pads[1][24]. As one of the most important components of bras, the underwire is designed to provide shape and transfer the downward pressure from the weight of the breasts to the bra band[24]. The breasts are pushed up and extruded from around to inside because of the patternmaking method used for underwired bras[25]. The underwire is opened approximately 2 cm when its pattern is drawn[25], which makes the cup shape extrude after the underwire is added. The stiffness of the unit of the breast and bra cup may be increased after the underwire is added. As breast motion decreases as breast stiffness increases[26], adding an underwire may be an effective method to reduce vertical breast motion. However, no study has yet investigated the relationship between the use of an underwire in bras and breast motion during exercise.

Given the lack of research on the effect of adding an underwire in bras on vertical breast motion and discomfort, the aim of this study was to investigate whether using an underwired bra can significantly decrease vertical breast motion and exercise-induced breast discomfort among women with large breasts during daily activities. It was hypothesised that using an underwired bra would result in less vertical breast displacement and perceived breast motion among women with large breasts during walking, jogging, and running on a treadmill than using an underwire-free bra. As exercise-induced breast discomfort was reported to be positively related to breast motion, we also hypothesised that exercise-induced breast discomfort would be lower in the underwired bra condition than in the underwire-free bra condition.

2. Methods

2.1. Participants
After obtaining approval from our institutional ethics committee, we recruited nine women with the following physical characteristics (mean ± standard deviation [SD]): upper breast circumference, 87.1 ± 5.0 cm; breast circumference, 87.6 ± 4.5 cm; and underbust circumference, 76.0 ± 6.8 cm to participate in this experiment. All participants were aged between 18 and 25 years, were not pregnant nor had they given birth, and had undergone no previous breast surgery. Participants with breast sizes of 75 C or 85 C were included. An experienced bra fitter checked the bra fit according to the fit criteria reported by Deirdre et al.[16] after each participant wore the experimental bras. All participants provided their informed consent to participate in the study.

2.2. Experimental conditions
A style of an underwired everyday bra (cup lining made from 100% cotton and wing lining made from 75% nylon and 25% spandex) with the brand name ‘Cosmo Lady’ was selected as the experimental bra, as shown in Figure 1. The experimental bra in the current study was selected to represent common bras available for women with large-sized breasts. Two experimental conditions were tested during the study, with each participant completing three running trials for each condition. Bra with and without the inclusion of an underwire formed the two experimental conditions.
2.3. Experimental procedures

All testing was conducted in a sports ergonomics laboratory at a local university. The participants wore their own running shorts and shoes during all testing for each experimental condition. Each trial consisted of the participant walking at 5 km/h, jogging at 7.5 km/h, and running at 10 km/h on a treadmill, as described previously [21]. The three treadmill speeds were selected on the basis of the speeds used in previous studies. Besides, walking is very common during daily life, typical jogging speed for women going for a run was about 7.5 km/h, and faster running speed was used in a lot of team sports. At the familiarisation period, each participant completed sufficient practice to ensure a consistent and steady exercise on the laboratory treadmill (H/P/Cosmos & Medical GmbH, Germany).

The participants’ breasts were considered symmetrical. The vertical displacement of each participant’s left breast was assessed. The vertical breast displacement of each participant relative to the torso was measured during each trial by tracking light-emitting markers (7.5-mm diameter). One marker was placed directly onto each participant’s skin overlying the sternal notch using a medical adhesive tape. The other marker was placed using a two-sided adhesive tape on the bra cup surface against the centre of the nipple to monitor breast motion.

The treadmill tests were undertaken in two random order bra conditions. The three-dimensional position of each marker was tracked using three cameras of the Optotrak motion capture system (Northern Digital, Ontario, Canada). In each bra condition, the treadmill speed was gradually increased from static condition to the walking speed of 5 km/h. The participants exercised for at least 30 s before 60-s data were collected at the speed of 5 km/h. Thereafter, the treadmill speed was decreased to a stop. There was a 5-min rest period between two bra condition running trials, during which the bra underwire was removed or added on the basis of the previous bra condition. Data were collected in the same procedure in the 5-km/h trial when the participants exercised in the other two speeds.

Feedback was obtained after the three speeds for a given bra. Perceived breast motion and exercise-induced breast discomfort were quantitatively rated by each participant using the visual analogue scale (VAS) (rated 0-10; 0 indicating no motion or discomfort or 10 indicating extreme motion or discomfort).

2.4. Statistical analysis
The vertical breast displacement for each trial was calculated (in mm) from the displacement data by removing the torso motion (characterised by the sternal notch marker) from the breast motion in the vertical plane. The mean values of the ten most representative vertical breast displacement values, derived from cycles in which all marker data were complete, were used for data analysis. The means and SDs of the vertical breast displacement and VAS scores for the perceived breast motion and discomfort were calculated for each of the two bra conditions. Preliminary descriptive analyses were conducted to check the assumptions of normality and homoscedasticity. Because the data of the vertical breast displacement were nonparametric (Kolmogorov-Smirnov and Shapiro-Wilk tests, p < 0.05), the related-samples Wilcoxon signed rank test was performed to compare the vertical breast displacement between the two bra conditions in each speed. The independent-samples Kruskal-Wallis test was employed to determine significant differences in the vertical breast displacement across the treadmill speeds. Post-hoc Mann-Whitney U tests were performed for multiple comparisons across the treadmill speeds. The perceived breast motion and discomfort were compared between the two bra conditions using the related-samples Wilcoxon signed rank test. All statistical analyses were deemed significant at p values of < 0.05.

To identify how well the underwired bra condition reduced breast motion and discomfort relative to the underwire-free bra condition, the reduced percentage of breast motion and discomfort was calculated using formulas (1)-(3).

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RVBD = \frac{(VBDf - VBDu)}{VBDf} \times 100\% \\
RPBM = \frac{(PBMf - PBMu)}{PBMf} \times 100\% \\
RPBD = \frac{(PBDf - PBDu)}{PBDf} \times 100\%
\]

where RVBD, RPBM, and RPBD represent the reduced percentage of vertical breast displacement, perceived breast motion, and perceived exercise-induced breast discomfort, respectively; VBDf, PBMf, and PBDf represent the vertical breast displacement, perceived breast motion, and perceived exercise-induced breast discomfort in the underwire-free bra condition, respectively; and VBDu, PBMu, and PBDu represent the vertical breast displacement, perceived breast motion, and perceived exercise-induced breast discomfort in the underwired bra condition, respectively.

All statistical analyses were computed using IBM SPSS Statistics Version 22 (SPSS Inc., Chicago, Illinois, USA).

3. Results

3.1. Vertical breast displacement
A significant effect of using the bra underwire was noted on the vertical breast displacement at each treadmill speed (all p < 0.01); the vertical breast displacement in the underwired bra condition was significantly lower than that in the underwire-free bra condition at each treadmill speed (Figure 2). The greatest reduced percentage of vertical breast displacement was 16.4% at the treadmill speed of 10 km/h, followed by 15.0% at 7.5 km/h and 7.1% at 5 km/h.

There was a significant effect of treadmill speed on the vertical breast displacement in both bra conditions (both p < 0.01). The post-hoc analysis revealed that each increment in the treadmill speed resulted in a significant increase in vertical breast displacement in the underwire bra and underwire-free bra conditions (all p < 0.01).

3.2. Perceived breast motion and breast discomfort
There was a significant effect of using the bra underwire on the perceived breast motion (p = 0.007) and exercise-induced breast discomfort (p = 0.025); the perceived breast motion and exercise-induced breast discomfort were significantly lower in the underwired bra condition than in the underwire-free bra condition (Figure 3). The reduced percentage of the perceived breast motion and discomfort was 27.8% and 37.5%, respectively.
Figure 2. Means ± standard deviations of the vertical displacement of the left breast relative to the trunk when the participants (n = 9) wore the underwired bra and the underwire-free bra; *Significant between-bra condition difference (p < 0.05).

Figure 3. Means ± standard deviations of the ranking of the perceived breast motion and exercise-induced breast discomfort when the participants (n = 9) wore the underwired bra and underwire-free bra; 0 represents no motion or discomfort, and 10 represents extreme motion or discomfort.*Significant between-bra condition difference (p < 0.05). VAS, visual analogue scale.
4. Discussion
This is the first study to determine whether adding an underwire to a bra could decrease breast motion and discomfort. The effects of using a bra underwire on vertical breast displacement, perceived breast motion, and exercise-induced breast discomfort are discussed below.

4.1. Vertical breast displacement
In this study, the vertical breast displacement of the C-cup participants during treadmill walking (5 km/h) was 8.4 mm in the underwire-free bra condition. The value calculated in this research compares well with the results (8.7 mm) in a previous literature[5], in which the vertical breast displacement of D-cup women in an encapsulation bra condition was reported in the form of a figure. Furthermore, given that an increase in the treadmill speed results in an increase in the vertical breast displacement [5], the measured vertical breast displacement (8.4 mm) during treadmill walking (5 km/h) in the current research is in line with the mean value (6.8 mm) of C-cup women during walking at a speed of 4 km/h reported previously[27]. Furthermore, the vertical breast displacement (24.4 mm) during running in the underwire-free bra condition also compares well with the value (26.0 mm) reported in another previous research[1].

Consistent with previous findings[5], the notion that an increase in the treadmill speed induces a significant increase in the vertical breast displacement was confirmed in the current research. Given that even walking yields noticeable accumulated vertical breast displacement, the value of the vertical breast displacement at higher-intensity exercises, such as jogging and running, is not difficult to determine, suggesting that reducing breast motion is necessary.

We found that removing the underwire significantly increased the vertical breast displacement at each speed. This indicates that adding an underwire was effective in significantly decreasing the vertical breast displacement. This result is consistent with hypothesis one: The vertical breast displacement significantly decreases if women wear an underwired bra compared with if they wear an underwire-free bra, with the other bra parts unchanged. A negative correlation has been reported to exist between breast displacement and breast stiffness, which indicated that breast displacement was greater in soft breasts than in hard breasts[26]. We anticipated that adding an underwire would increase the stiffness of unit of the breast and bra cup and consequently reduce breast motion. It is also possible that the ‘pushing up’ and ‘encapsulation’ effects of adding an underwire help the bra cup reduce the vertical breast displacement, considering the principle involved in encapsulation sports bras[2]. Previous studies found that changes in bra cup design such as adding elevation and compression[2] and changes in bra shoulder strap design such as altering strap orientation from the traditional direction to the crossed-back direction[18][23] were not efficient in decreasing vertical breast displacement; these findings may indicate a new direction for bra designs aimed at reducing vertical breast displacement.

4.2. Perceived breast motion and exercise-induced breast discomfort
Despite jogging and running the overall discomfort levels were very low and the change between bras was small (1 versus 1.5). Given the very mild discomfort levels then it would be unlikely that participants would need to jog/run with a different trunk lean in order to reduce discomfort/pain levels. This indicates that the trunk lean different related to discomfort between the two bra conditions could not influence the comparison of vertical breast displacement.

Consistent with hypothesis two, the women with large breasts perceived less breast motion when they wore an underwired bra than when they wore an underwire-free bra during treadmill exercise. The result related to the subjective evaluation on breast motion is also consistent with the results related to the objective vertical breast displacement measurements. The fact that the underwired bra condition yielded less vertical breast displacement than did the underwire-free bra condition was correctly perceived by the participants. Expectedly, the exercise-induced breast discomfort was also lower when the participants wore an underwired bra than when they wore an underwire-free bra. Previous studies have reported that the exercise-induced breast discomfort decreased when the vertical breast
displacement was reduced[2-3][7]. In the current study, the vertical breast displacement was lower in the underwire bra condition than in the underwire-free bra condition, which may explain why the participants perceived less exercise-induced breast discomfort when they wore an underwired bra than when they wore an underwire-free bra. As perceived breast discomfort was one of the barriers for performing sufficient physical activity among women with large breasts[2], wearing underwired bras may increase their breast comfort and then increase their participation in physical activity, which would then positively impact their physical and psychological health.

4.3. Strengths and limitations
There are some limitations in this study. First, the sample size was small. Second, only one product was used. Third, it is not clear how bra underwire parameters (e.g. length, width, or stiffness) influence the bra’s function of controlling breast motion, which warrants further research. Last, only the vertical breast displacement was assessed; the breast displacement in the mediolateral and anteroposterior directions was not evaluated. Despite these limitations, the current research is the first study to explore the effect of including a bra underwire on breast motion and discomfort. Moreover, the method used in the current study ensured that the underwire was the only variable in the bra during the entire testing procedure; we thus avoided the interference of other factors, such as material content difference in the two bra conditions.

5. Conclusion
This investigation revealed that adding an underwire to a bra resulted in significantly less vertical breast displacements and lower subjective ratings of perceived breast motion and exercise-induced breast discomfort among the women with large breasts than did removing an underwire. These results provide scientific evidence regarding the addition of an underwire in the design of a bra to minimise breast motion and exercise-induced breast discomfort, particularly for women with large breasts. Further investigations are warranted to determine whether adding an underwire to a bra affects bra discomfort, which is another important factor related to physical activity.

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