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HOW DO BRA STRAP ORIENTATION AND DESIGN AFFECT THE COMFORT OF WOMEN WITH LARGE BREASTS?

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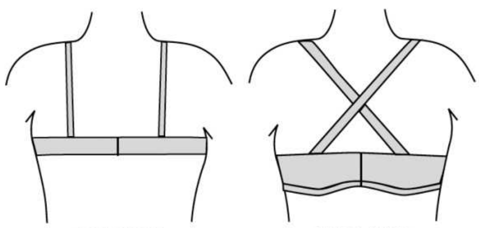
INTRODUCTION

Encapsulation style sports bras reduce breast motion and exercise-induced breast pain in women with large breasts more effectively than crop tops [1]. Less than 50% of women, however, wear encapsulation style sports bras during exercise because they are deemed too uncomfortable to wear [2]. The main source of this discomfort among exercising women is typically the bra straps [2]. For example, it was recently revealed that 68% of 106 respondents disliked bra straps "cutting in", whereas 57% of respondents disliked bra straps "slipping off their shoulders" [3]. Despite bra straps being a primary cause of discomfort, no research has systematically examined the influence of modifying bra strap design and orientation on strap comfort. Therefore, the aim of this study was to investigate the effects of altering bra strap orientation and design on bra strap comfort for women with large breasts when they exercise wearing an encapsulation style sports bra.



(A) (B)

Figure 1: A posterior view of the two bra strap orientations: (A) the vertical strap; and (B) the cross-back strap orientations (from McGhee *et al.* [5], page 27).

METHODS

Twenty-three women (age: 22.3 ± 2.6 years; height: 168.5 ± 5.0 cm; body mass: 66.3 ± 6.5 kg) who were correctly fitted to wear a D+ cup size encapsulation style sports bra (New Legend Underwire sports bra, Berlei, Australia) and who exercised for at least 5 hours per week were recruited as representative of active women with large breasts. Once fitted, the participants completed a short questionnaire about their current sports bra usage and exercise history.

Six randomly-allocated bra strap conditions, incorporating two strap orientations (vertical and cross-back; correctly fitted to each participant's torso; Figure 1) and three strap designs (standard, wide and gel), were then assessed while the participants stood still (static trials) and while running on a PowerJog treadmill at 9.1 ± 0.3 kph (dynamic trials). The three strap designs were made from materials commonly used in bra strap design (industrial grade bra wadding: 100% polyester outer, 65% polyprople/35% polyester inner; cotton spandex: 95% cotton, 5% spandex; and satin power mesh: 88% nylon, 12% spandex mesh). The width of the standard strap was based on the width of commercially available bra straps (2.5 cm) and the wide strap was significantly wider (4.5 cm) than the standard strap. The gel strap design contained a Dermis Plus Polymer gel pad (10 cm x 3 mm x 10 cm; MacMed Health Care, Australia), cut into four equal pieces and placed under the standard bra straps, in direct contact with the participant's skin.

During the dynamic trials bra discomfort was rated for each condition (0-10) using a visual analogue scale (VAS), whereby 0 represented "no discomfort" and 10 represented "worst possible discomfort". Bra strap pressure (kPa) and vertical breast displacement (VBD; cm) were also recorded for six 10-s intervals between the 1st and 3rd minute for each condition (dynamic trials) with at least 5 minutes rest between conditions to prevent fatigue and to change bra strap condition. Strap pressure was measured at the strap-shoulder interface using a custom pressure sensor (10 mm² diameter; 0.5-24 kPa; 50 Hz, Novel$_{gmbh}$, Germany), placed at the crest of the shoulder under the bra strap on the participant's right side, and Pliance-x Expert Online software (Version 10.3, Novel$_{gmbh}$, Munich, Germany). The average of the six 10-s periods per bra strap condition was calculated to represent dynamic strap pressure. VBD was quantified using IRED markers (200 Hz, Optotrak Certus® system, Northern Digital, Canada) placed on each participant's nipples and torso (sternal notch). VBD was calculated by subtracting torso motion from nipple motion in the vertical plane. Average displacement of each participant's right and left nipples were then calculated from a representative 15-20 consecutive breast cycles, for each of the six 10-s data recordings per condition.

Before and after each dynamic trial, static recordings of VBD and bra strap pressure were recorded for 10-s and participants were asked to rate their bra, breast and strap discomfort (VAS), how much they liked or disliked the bra strap condition, as well as their rating of perceived exertion. Participants also selected their most preferred and least preferred bra strap design, as well as their preferred bra strap orientation at the completion of all dynamic running trials.

A two way ANOVA with two within factors (strap orientation and strap design) and Tukey *post hoc* analyses were used to determine whether there were any significant ($p < 0.05$) main effects or interactions of strap orientation (vertical, cross-back) or strap design (standard, wide, gel) on the discomfort scores, bra strap pressure or VBD for the six bra strap conditions.

RESULTS AND DISCUSSION

Consistent with previous research [3], 61% of participants reported problems with the straps of their own sports bras, highlighting the continued need for improvements in bra strap design. Interestingly, 35% of participants reported changing the orientation of their bra straps to fit the design of clothing they wore when exercising, in most cases (63%) sacrificing comfort to do so. It is therefore imperative that manufacturers consider sports bra straps when designing exercise clothing, as this will have important implications for the comfort of women with large breasts.

Effect of bra strap orientation: Bra strap discomfort was significantly less in the vertical (0.6 ± 1.2 score) compared to the cross-back strap orientations (1.4 ± 1.6 score; $p \leq 0.001$). VAS results, however, should be interpreted with caution, as the scores were low (average scores ranged from 0.5 ± 0.9 to 2.1 ± 2.1). As bra-wearing duration is likely to influence strap comfort, assessing strap discomfort over a longer time may elicit greater changes in discomfort scores. 70% of participants rated the vertical strap orientation as more comfortable than the cross-back strap orientation and the vertical as the most preferred bra strap orientation. This was because the vertically-orientated straps “don’t dig in” or “don’t create pressure” on the shoulders or across the trapezius muscle. There was no significant difference in bra strap pressure ($p = 0.466$) or VBD ($p = 0.510$) between the two strap orientations.

Effects of bra strap design: Participants rated the wide bra strap as causing lower bra strap discomfort compared to both the standard and gel bra strap designs, although this difference (~ 1 VAS score) was not statistically significant. Participants (n = 8, 35%) also rated the wide, vertical strap condition as the most preferred strap condition. The top three reasons cited for this preference were that the participants felt the wide strap: (i) cushioned the load borne by the straps; (ii) was comfortable; and (iii) they “couldn’t feel it”. When grouped by design alone, the participants rated the gel strap as the most preferred design (n = 11, 48%), stating they liked the “feel” of the gel material on their shoulders and reporting that it “cushioned” the load.

When the data were pooled across strap orientation, dynamic bra strap pressure was significantly greater in the gel strap design condition (6.4 ± 1.7 kPa) compared to both the wide (3.7 ± 1.3 kPa; $p < 0.001$) and standard (5.6 ± 1.5 kPa; $p = 0.014$) strap design conditions and in the standard compared to the wide strap design condition ($p < 0.001$). The low pressures recorded in the wide bra strap condition (Table 1) confirm that the greater surface area afforded by a wider bra strap enables a greater area over which to distribute the force compared to a standard width bra strap [4]. Contrary to expectations, the highest bra strap-shoulder interface pressures were recorded in the gel strap conditions, during both the static and dynamic trials. However, the strap conditions in which the highest pressures were recorded were not the conditions that were rated by the participants as the most uncomfortable or least preferred. Finally, there was no difference in VBD between the six bra strap conditions (average across conditions = 3.18 ± 0.97 cm), such that bra strap orientation and design did not affect breast motion when the participants were correctly fitted in their encapsulation bras.

CONCLUSIONS

It is recommended that, in order to increase bra strap comfort while maintaining breast support, women with large breasts would benefit from wearing wide bra strap designs. Placing a gel pad under the strap of the bra will also increase bra strap comfort and could minimize the incidence of bra straps slipping off the shoulders. If comfort is still problematic, it is recommended that these women also consider altering the orientation of their wider bra straps to a vertical orientation, although their preferred strap orientation is likely to be influenced by their individual morphological characteristics.

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Table 1: Mean ± standard deviation and confidence interval (CI) values for the static and dynamic pressure (kPa) recorded at the bra strap-shoulder interface for each of the six bra strap conditions (n = 23).

	Static	95% CI		Dynamic	95% CI	
		Lower bound	Upper bound		Lower bound	Upper bound
Vertical orientation						
Standard	4.6 ± 1.3	4.0	5.2	5.4 ± 1.3	4.8	5.9
Wide	3.4 ± 2.0	2.5	4.3	3.9 ± 1.3	3.4	4.5
Gel	6.0 ± 1.6	5.4	6.8	6.6 ± 1.5	5.9	7.2
Cross-back orientation						
Standard	5.3 ± 1.7	4.5	6.1	5.7 ± 1.7	4.9	6.4
Wide	3.3 ± 1.0	2.8	3.8	3.4 ± 1.2	2.9	4.0
Gel	6.1 ± 2.4	5.1	7.4	6.2 ± 1.8	5.4	7.0