Effects of elasticity distribution of sports bras on breast support and pressure comfort performance for senior females

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ABSTRACT – REZUMAT

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Sports bras efficient in the reduction of breast displacement (RBD) were always rated low in pressure comfort performance. Elasticity distribution was found to be influential in RBD and pressure distribution in the under-band; however, the effects of other parts have yet to be studied. This study aimed to investigate the effects of elasticity distribution on RBD and pressure comfort for the optimisation of these two performances for senior females. Five sports bras with different elasticity distribution in 5 parts (front strap, back strap, cup, back panel, and under-band) were developed to compare with the one without elasticity distribution. 20 senior female participants were involved, and the RBD, dynamic peak pressure and compressive feelings at four test points were measured and analysed by ANOVA. The results indicated that Bra A, C, and E significantly improved RBD in all three directions (P<0.001), Bra D enhanced RBD in direction Z (P<0.001), while Bra B showed no significant effect in any direction. The effect on pressure varied with the specific placement of the test point relative to the high-Young's modulus part of the sports bra, and the compressive feelings of Bra A and E were below 3 at all four test points. Comprehensively, the elasticity distributions of applying high-Young's modulus in the front straps (Bra A) and under-band (Bra E) were ideal and typical, which significantly enhanced RBD without inducing discomfort, and provided novel information in optimising RBD and pressure comfort for the sports bras industry and the exercising senior females.

Keywords: *senior females, sports bra, elasticity distribution, breast displacement, pressure comfort*

Efectele distribuției elasticității bustierelor sport asupra susținerii bustului și a confortului la presiune pentru persoanele vârstnice de sex feminin

Bustierele sport eficiente în reducerea deplasării bustului (RBD) au fost întotdeauna evaluate ca având un confort scăzut la presiune. S-a constatat că distribuția elasticității are o influență asupra RBD și asupra distribuției presiunii în zona benzii inferioare; cu toate acestea, efectele celorlalte părți nu au fost încă studiate. Prezentul studiu și-a propus să investigheze efectele distribuției elasticității asupra RBD și asupra confortului la presiune, în vederea optimizării acestor două caracteristici pentru persoanele vârstnice de sex feminin. Au fost dezvoltate 5 bustiere sport cu distribuție diferită a elasticității în 5 părți (breteaua frontală, breteaua din spate, cupa, panoul din spate și banda inferioară) pentru a fi comparate cu cel fără distribuție a elasticității. Au participat 20 de persoane vârstnice de sex feminin, iar RBD, presiunea maximă dinamică și senzațiile de compresie în patru puncte de testare au fost măsurate și analizate prin ANOVA. Rezultatele au indicat că bustierele A, C și E au îmbunătățit semnificativ RBD în toate cele trei direcții (P<0,001), bustiera D a îmbunătățit RBD în direcția Z (P<0,001), în timp ce bustiera B nu a prezentat niciun efect semnificativ în nicio direcție. Efectul asupra presiunii a variat în funcție de amplasarea specifică a punctului de testare în raport cu partea cu modulul Young ridicat al bustierei sport, iar senzațiile de compresie ale bustierelor A și E au fost sub 3 în toate cele patru puncte de testare. În ansamblu, distribuțiile elasticității obținute prin utilizarea unui modul Young ridicat la bretelele frontale (bustiera A) și la banda inferioară (bustiera E) s-au dovedit ideale și tipice, ceea ce a îmbunătățit semnificativ distribuția presiunii (RBD) fără a provoca disconfort și a oferit informații noi privind optimizarea RBD și a confortului la nivel de presiune pentru industria bustierelor sport și pentru persoanele vârstnice de sex feminin care practică exerciții fizice.

Cuvinte-cheie: *persoane vârstnice de sex feminin, bustieră sport, distribuția elasticității, deplasarea bustului, confortul la presiune*

INTRODUCTION

The demographic pressure resulting from the ageing population is one of the most pressing global concerns [1]. Encouraging elderly individuals to engage in low-intensity physical activities is beneficial for their health and helps alleviate the burden on the social healthcare system. However, during physical activity, women's breasts experience movement relative to the chest wall due to the limited anatomical support, which may result in exercise-related breast pain, the risk of breast sagging or even breast diseases [2]. And the situation becomes more pronounced in senior females, as the skin covering the breasts loses elasticity, the connective tissues become less resilient as a result of a decline in reproductive hormones, estrogen [3]. A sports bra is proven to be effective in reducing the range of movement (ROM) of the breast; however, it also exerts pressure on the body due to the fabric's tensile behaviour, which may lead to discomfort, skin irritation or even injuries in cardiopulmonary function [4]. Besides, the sports bras efficient in breast support often generated higher pressure to females, or were rated low in comfort performance, resulting in a contradiction in sports bras design. For example, Lu et al. observed that a cup with a pad decreased the breast movement but also increased contact pressure, compared to the cup without a pad [5]. Celeste et al. found a lower ROM for cross-back straps when compared to the vertical straps; however, it was also rated low in pressure comfort of the shoulder [6].

Moreover, most of the research focused on the reduction of breast displacement (RBD) or pressure comfort, with limited research focused on the optimisation of these two performances. For senior females, whose breast tissue mechanical properties have declined and become more sensitive to pressure, optimising both support performance and pressure comfort is crucial. Elasticity distribution, i.e., using fabrics of different Young's modulus (a property that quantifies fabric deformation under applied external forces) in different parts [7], is a widely utilised approach to enhance pressure comfort. According to Laplace's law, the pressure exerted by the sports bra is determined by fabric tension and the radius of body curvature [5]. Therefore, variations in Young's modulus in different parts, for the same elongation, will lead to differences in fabric tension and, consequently, alter the pressure distribution. Given the variation in pressure comfort thresholds (PCT, defined as the boundary between pressure comfort and discomfort) across different body regions [8], rational pressure distribution may improve pressure comfort. For instance, Liu et al. presented a new computational pipeline for designing and fabricating 4D garments as knitwear by careful control of elasticity distribution to reduce pressure and fabric sliding [7]. Zheng et al. found that the seamless bras knitted with different loop lengths in different regions provided better comfort to wearers than commercial bras [9]. Recently, researchers found that applying knitting structures with high Young's modulus in the side area of the under-band was effective both in RBD and pressure comfort performance of 4 points covered by the under-band [10]. However, this research predominantly focused on the under-band, while the effects of the elasticity of the whole sports bra have yet to be studied.

In addition, most existing studies on RBD or pressure comfort focused on young women and the movements of running and jumping. The change in anatomical structure and mechanical properties for breast tissues associated with ageing may lead to differences in the results of RBD and pressure comfort. Besides, due to the decline of physiological and psychological exercise capabilities of the elderly, they are encouraged to participate in some low-intensity activities, rather than high-intensity activities such as running and jumping.

This study aimed to explore the effect of the elasticity distribution of sports bras on RBD, pressure distribution and pressure comfort, searching for an optimal elasticity distribution which was effective in improving the support performance without decreasing the pressure comfort of the sports bra for senior females. Consequently, five sports bras with different elasticity distribution (applying high-Young's modulus fabric in front strap, back strap, cup, back panel, and under-band respectively) and one without elasticity distribution (as a control bra) were designed. Forwards-backwards stepping, i.e., a typical movement of square dancing (a widely popular and highly recommended low-intensive exercise for senior females in China, which was proven to be effective in delaying the ageing process), was selected as the experimental movement. RBD, dynamic peak pressure, and psychological pressure comfort sensations of these six sports bras were measured and compared. It was hypothesized that: (1) the elasticity distribution of these five sports bras would significantly improve the reduction of breast displacement (RBD), compared to the control bra; (2) the elasticity distribution of these five sports bras would generate significantly higher dynamic peak pressure, compared to the control bra; (3) based on variations in pressure comfort threshold (PCT) across different body regions, sports bras with rationally designed elasticity distribution would improve the reduction of breast displacement (RBD) without inducing pressure discomfort.

METHODOLOGY

Participants

Following institutional ethical approval, twenty healthy Chinese senior females (aged 60–65 years) from three cities of China (Hangzhou, Shanghai, and Nanjing) were recruited as participants. It has been observed that breast morphology changed in the ageing process, primarily manifesting as increased breast volume, ptosis, and lateral extension, which might affect the breast movement and contact pressure. Therefore, eight anthropometric items of the participants were measured (as shown in table 1), and the participants were selected according to the average anthropometric measurements of Chinese senior females (mean bust girth: 96.70 ± 7.41 cm, mean under-bust girth: 84.23 ± 7.82 cm, mean bust to under-bust difference: 12.47 ± 2.82 cm, mean bust point width: 18.50 ± 1.30cm, mean length from front neck point to bust point: 23.13 ± 2.22 cm, most common cup size: 85B), derived from a survey of 115 Chinese senior females, to minimize the potential between-participant effect in RBD and pressure comfort. The 3D body scanner (TC)[2] (US) was used to measure the subjects, and all participants were professionally fitted with an 85B bra size. All subjects had gone through pregnancy, breastfeeding, and

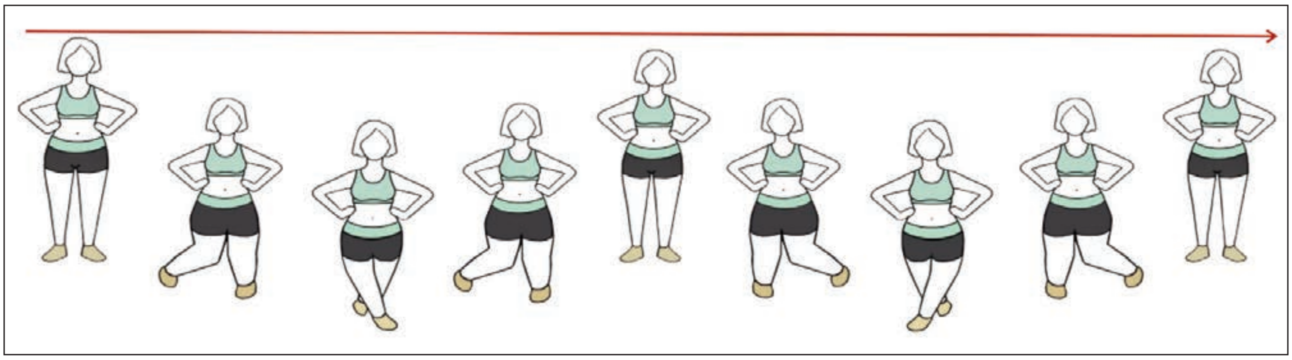


Fig. 1. The illustration of forward-backwards stepping

menopause, experienced no surgical procedures to the breasts, and undertook ≥30 min of exercise more than 4 times a week.

Forwards-backwards stepping, i.e., a typical movement which accounts for 94% of all motions in square dance, was chosen as the experimental movement (figure 1).

Table 1

ANTHROPOMETRIC MEASUREMENTS OF THE SUBJECTS	
Anthropometric measurements	**Mean (Std. D)**
Age (years)	62.60 (1.31)
Height (cm)	158.64 (1.28)
Weight (kg)	61.83 (1.52)
Bust girth (cm)	97.43 (0.56)
Under-bust girth (cm)	84.62 (0.46)
Bust to under-bust difference (cm)	12.81 (0.43)
Bust points width (cm)	18.57 (0.41)
Length from front neck point to bust point (cm)	23.31 (0.41)

Experiment samples

Research showed that well-fitting bras for senior females typically incorporate features such as wide straps, sufficient vertical cup length, higher gore and underarm height, and a rigid under-band, due to morphological changes [11]. Therefore, a compression sports bra with the design features mentioned above was used as the prototype for the experiment samples.

The elasticity distribution of the samples was based on four pressure test points, namely the peak point of shoulder (Point a), the midpoint of the upper scapular region (Point b), the intersection point of under-bust line with the lateral line (Point c), the midpoint between lateral root and the bottom of the breast (Point d), as shown in figure 2, *c*. Point a and c were often reported for pressure discomfort [6]. Points b and d of the elderly women may experience higher pressure compared to young women, due to a forward bending curvature, which is commonly observed in senior females, resulting from kyphosis, and the sagging and lateral extension of breasts [3]. Therefore, the sports bra was divided into 5 parts (front strap, back strap, cup, back panel, and under-band) based on these four test points, to ensure each test point was covered by a different part. To avoid the potential slippage of the peak point of the shoulder (Point a) between the front strap and back strap during physical activity, the front strap was extended 2 cm backwards to ensure continuous coverage of this point by the front strap, as shown in figure 2, *a*.

Two commonly used rib-knitting fabrics with different levels of Young's modulus (F_3~F_4) were selected for the elasticity distribution of the under-band, and two popular weft-knitting fabrics with different levels of Young's modulus (F_1~F_2) were chosen for the front straps, back straps, cups and back panels. The under-band was made of double layers of fabrics, while the other parts were made of a single layer, based on the common types of compression sports bras in the market. The control bra (Bra F) was made

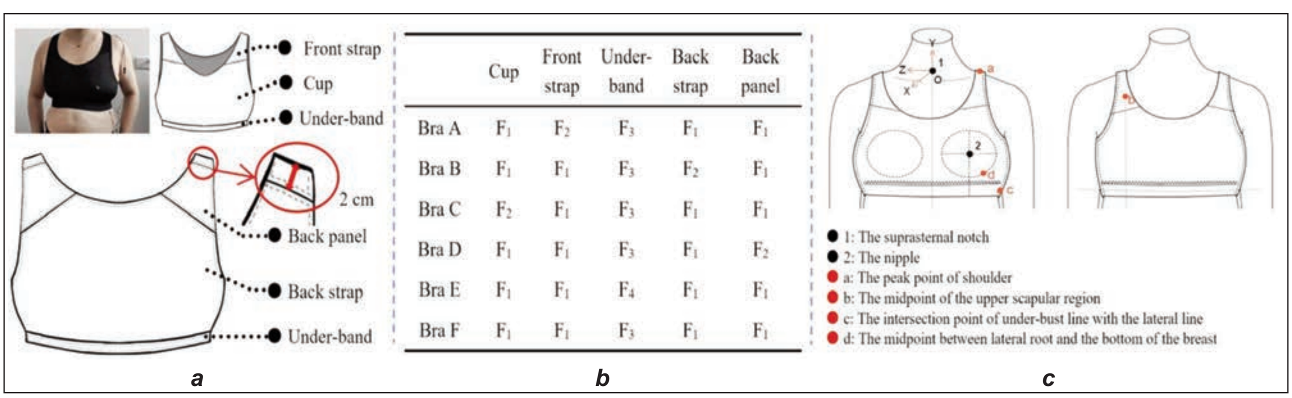


Fig. 2. Experiment details: *a* – structure details of the experimental sample; *b* – elasticity distribution details of the experimental samples; *c* – the trunk local coordinate system (LCS) and the pressure test points

Table 2

PHYSICAL PROPERTY SUMMARY OF THE FABRICS SAMPLES					
Fabric	**Fabric content**	**GSM (g/m^2)**	**Thickness (mm)**	**E (MPa)**	**p**
F_1	55.1% polyester, 31.7% polyamide, 13.2% spandex	233.60	0.817	1.7235	0.21
F_2	88.7% polyester, 11.3% spandex	315.90	0835	2.8179	0.16
F_3	66.1% polyester, 20.7% polyamide, 13.2% spandex	552.30	1.579	2.3191	0.08
F_4	82.8% polyester, 17.2% spandex	565.10	1.623	3.3563	0.07

Note: The results of F_3 and F_4 were obtained from the tests in which fabrics were folded into double layers to simulate the real wearing conditions of the under-bands.

of fabrics with lower Young's modulus (F_3 for under-band, F_1 for other parts), while the elasticity distribution bras were made of higher Young's modulus in one certain part, and lower Young's modulus in the other four parts, as shown in figure 2, *b*. As the thickness may affect the contact pressure, fabrics were selected with limited differences in thickness between F_1 and F_2, F_3 and F_4. The only differences among these six sports bras were the elasticity distribution; other features, such as style, structure, size, and production methods, were kept the same.

The tensile test was conducted with a tensile testing machine (Instron, USA), according to the Standard FZ/T 70006-2004. The Gramme per Square Meter (GSM) was measured using an electronic balance (XingYun, China) based on the Standard GB/T 4669-2008. The thickness test was carried out with a fabric thickness tester (YG, China) according to the Standard GB/T 3820-1997. The Poisson's ratio (p) was tested with the tensile testing machine (Instron, USA) and a high-definition camera (SONY, Japan). All tests were repeated five times, and the mean value was taken as the average of five test results. The physical properties of the fabrics (F_1~F_4) were summarised in table 2.

Experiment protocol

Motion capture

The breast motion when wearing six sports bras and when naked was captured by the motion capture system (Qualisys, Sweden). A parallel, randomised, blinded design wear trial was carried out. The temperature of the lab was set as 20±2°C, with an average relative humidity of 65 ± 3%. During forward-backwards stepping, as the torso mainly moves in vertical and anterior-posterior direction, the suprasternal notch was chosen as the reference point, while the nipple was chosen as the measuring point for breast movement. A trunk local coordinate system (LCS) based on these two points was established (x: anterior-posterior, y: vertical, z: medial-lateral), which had demonstrated high accuracy in exercises characterised by predominant trunk translation in previous research [5, 6, 12–14]. Two retro-reflective markers were attached to these two points (the suprasternal notch and the nipple, as shown in figure 2, *c*). The relative displacement of the breast was calculated by subtracting the displacement data of the suprasternal notch from that of the nipple, and ROM was determined by the differences between the peak and the trough of the relative displacement curves in gait cycles.

A 30-cycle duration at a frequency of 23 cycles/minute was chosen for the experiment. The middle consecutive 10 gait cycles (the 11^{th}~20^{th}) were selected for analysis. Each sample was tested 3 times, and the mean ROM after wearing each sports bra was taken as the average of the ROM in 30 gait cycles (10 gait cycles multiplied by 3 times). 5-min rest was taken between two test times for each sports bra, and 20 min rest was taken before wearing the next sports bra. Based on ROM, the reduction of breast displacement (RBD) was calculated (breast displacement (braless) minus breast displacement wearing a bra, divided by breast displacement (braless)) [15].

Dynamic peak pressure test

The dynamic peak pressure test was carried out simultaneously with the motion capture, using a pressure testing system (MFF, China), with the pressure sensors (FlexiForce, USA) attached to 4 test points as previously described, as shown in figure 2, *c*.

Similarly, the middle consecutive 10 gait cycles (the 11^{th}~20^{th}) of the total 30 gait cycles were chosen for analysis, and the mean dynamic peak pressure was taken as the average of the peak pressure in the total 30 gait cycles (10 gait cycles multiplied by 3 times).

Subjective pressure comfort test

The pressure comfort was assessed by surveying the wearers regarding their subjective compressive feelings at these 4 test points, using a compressive feeling scale (rated 1~5) developed by Liu et al. [16] and modified according to the samples and pressure test points of this study. Where 1, 2, 3, 4, and 5 represented compressive feelings of extremely weak, weak, neutral, strong, and extremely strong, respectively, and the dynamic peak pressure rated as 3 or below 3 was deemed appropriate, indicating the pressure was acceptable and unlikely to induce discomfort. Compressive feelings were evaluated immediately after the motion capture and pressure test. The test for each sports bra was also repeated 3 times, and the mean compressive feeling when wearing each sports bra was calculated as the average of the three test results.

RESULTS AND DISCUSSION

The effects of elasticity distribution on breast displacement

The multi-planar displacement of the breast when wearing six sports bras of a representative subject (S_1) during one typical gait cycle of forwards-backwards stepping is exhibited in figure 3. The maximum breast displacement occurred in direction Y, followed by direction Z and X. The breast displacement curve in all three directions undergoes four phases, consistent to four stages of the trunk displacement curve in vertical direction (labelled as phases A, B, C, and D in figure 3, *a*), indicating that breast displacement was mainly affected by the trunk movement in direction Y during forwards-backwards stepping, which was much larger than the other two directions.

RBD of 6 sports bras in 3 directions were exhibited in figure 3, e, which showed the highest RBD in the vertical direction (RBD_y: 53.19 ± 1.11% ~ 64.51 ± 0.92%), followed by the medio-lateral direction (RBD_z: 39.69 ± 0.85% ~ 51.23 ± 1.24%) and the anterior-posterior direction (RBD_x: 30.41 ± 1.14% ~ 41.11 ± 1.09%). The data of RBD in three directions when wearing these six sports bras were found to be parametric (Kolmogorov–Smirnov and Shapiro–Wilk, $p>0.05$), and significant differences in bra by direction interaction effect ($F = 524.799$, $P < 0.001$, $\eta^2_{partial} = 0.958$) in RBD were detected by repeated-measures analysis of variance (ANOVA). Bra A performed best in direction X (41.11 ± 1.09%) and Y (64.51 ± 0.92%), while Bra C performed best in direction Z (51.23 ± 1.24%). Bra A, C and E exhibited significantly higher RBD than Bra F in all three directions ($P < 0.001$), Bra D significantly enhanced RBD in direction Z ($P < 0.001$), while Bra B showed no significant difference in RBD with Bra F in any direction, rejecting the first hypothesis.

The results indicated that applying fabrics with high Young's moduli in the front strap (Bra A), cup (Bra C) and under-band (Bra E) achieved significant effects in improving RBD in all three directions. High Young's modulus in the under-band may result in the increasing of contact pressure and body-bra friction, reducing under-band slippage [10], while high Young's modulus in the cup may lead to high fabric tension, effectively limiting breast movement and consequently enhancing RBD. Specifically, researchers have shown that a high Young's modulus of the entire strap contributed to improved RBD [17]. However, the differences between the front and back parts were not detected. The results of this study revealed that high Young's modulus in the front strap effectively improved RBD, rather than the back strap.

The effects of elasticity distribution on dynamic peak pressure

The data of dynamic peak pressure at four test points when wearing six sports bras were found to be parametric (Kolmogorov–Smirnov and Shapiro–Wilk, $p > 0.05$), and significant differences in bra by test point interaction effect ($F = 77.079$, $P < 0.001$, $\eta^2_{partial} = 0.772$) in dynamic peak pressure were detected by repeated-measures analysis of variance (ANOVA). Compared to Bra F, Bra A showed significantly higher pressure at Points a, b, and d ($P < 0.001$), while Bra B exhibited significantly higher

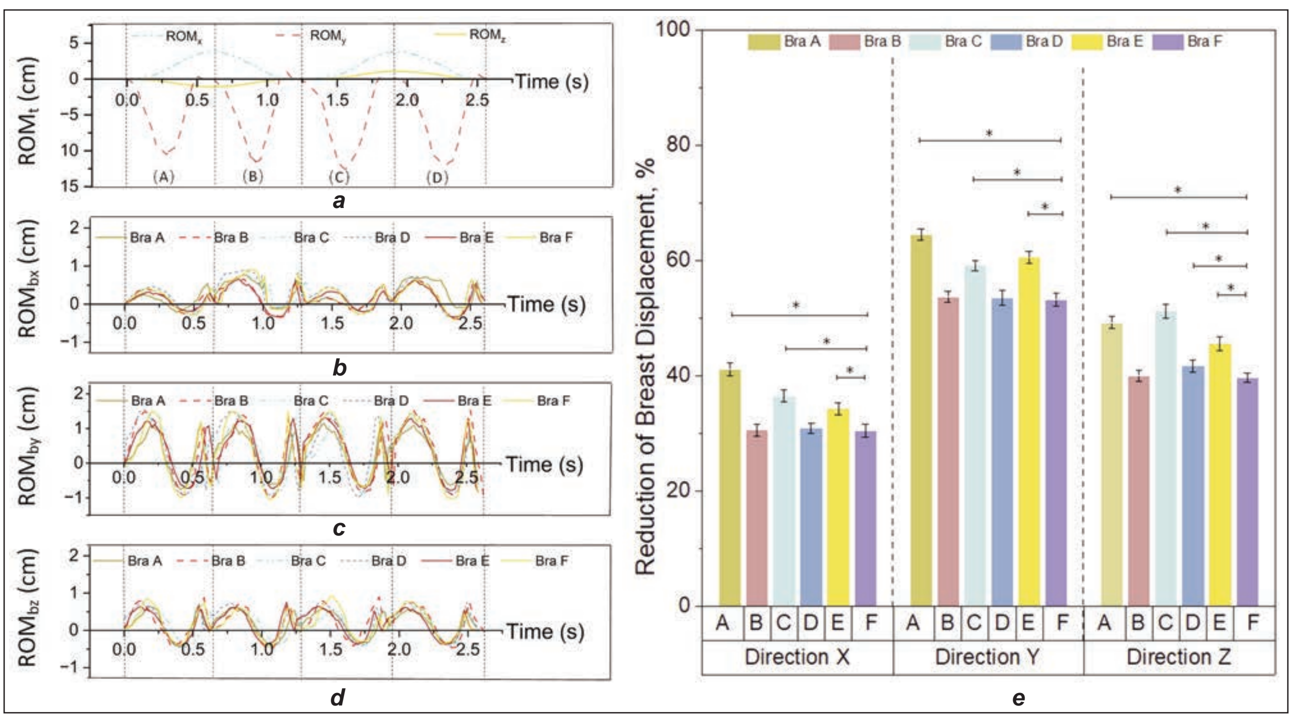
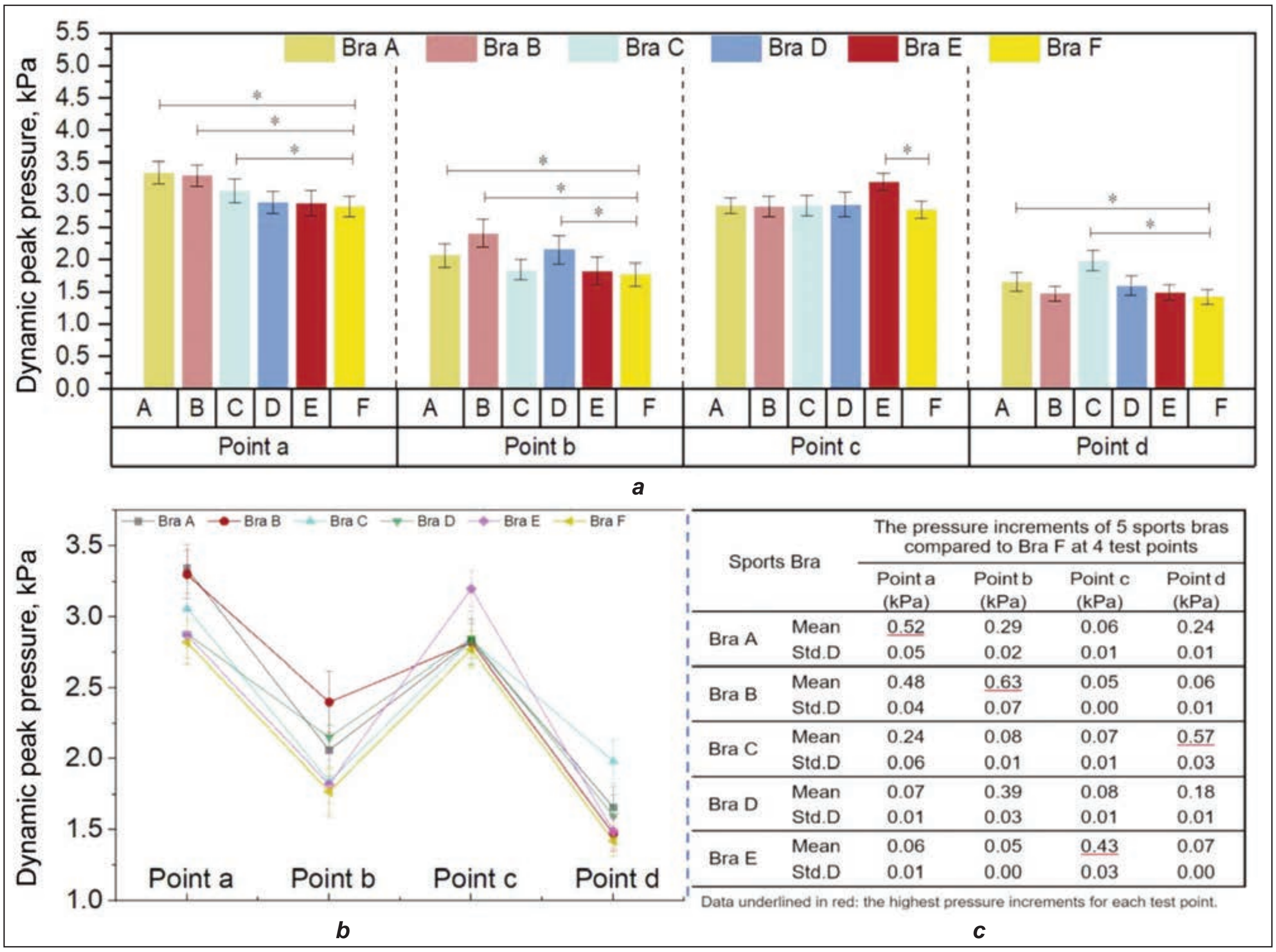


Fig. 3. The displacement of trunk and breast of a representative subject (S_1) during one typical gait cycle of forwards-backwards stepping: *a* – range of trunk movement (ROM_t); *b* – range of breast movement in direction X (ROM_{bx}); *c* – range of breast movement in direction Y (ROM_{by}); *d* – range of breast movement in direction Z (ROM_{bz}); *e* – reduction of breast displacement (RBD)



Sports Bra		The pressure increments of 5 sports bras compared to Bra F at 4 test points			
		Point a (kPa)	Point b (kPa)	Point c (kPa)	Point d (kPa)
Bra A	Mean	0.52	0.29	0.06	0.24
	Std.D	0.05	0.02	0.01	0.01
Bra B	Mean	0.48	0.63	0.05	0.06
	Std.D	0.04	0.07	0.00	0.01
Bra C	Mean	0.24	0.08	0.07	0.57
	Std.D	0.06	0.01	0.01	0.03
Bra D	Mean	0.07	0.39	0.08	0.18
	Std.D	0.01	0.03	0.01	0.01
Bra E	Mean	0.06	0.05	0.43	0.07
	Std.D	0.01	0.00	0.03	0.00

Data underlined in red: the highest pressure increments for each test point.

Fig. 4. The comparison of mean dynamic peak pressure between samples: *a* – the differences in the mean dynamic peak pressure; *b* – the pressure distribution; *c* – the pressure increment of Bra A, B, C, D, E, compared to Bra F

pressure at Points a and b ($P < 0.001$). Bra C significantly increased pressure at Point a and d ($P < 0.001$), Bra D generated significantly higher pressure at Point b ($P < 0.001$), while Bra E significantly increased pressure at Point c ($P < 0.001$), as shown in figure 4, *a*. All five sports bras generated significantly higher dynamic peak pressure at certain test points, but no significantly differences were found at other test points, compared to bra F. Therefore, the second hypothesis was partially accepted.

Concerning pressure distribution, crossed curves of 6 sports bras were observed (figure 4, *b*), indicating varied pressure distribution of each bra. Compared to bra F, the pressure at each point of the other 5 bras increased (figure 4, *c*), suggesting that applying a high Young's modulus in any part of the sports bra resulted in pressure increase at all test points. However, the pressure increment at each point varied across different elasticity distributions. For points a, b, and d, bras with high Young's modulus in the parts covering the test point and the part adjacent to the test point in the stretching direction showed greater pressure increments, while bras with high Young's modulus in the parts far away from the test point exhibited smaller increments. For example, Bra A (with high Young's modulus in front strap covering Point a) demonstrated the highest dynamic pressure increment at Point a (0.52 ± 0.05 kPa), followed by Bra B and Bra C (0.48 ± 0.04 kPa and 0.24 ± 0.06 kPa respectively, with high Young's modulus in back strap and cup), while Bra D and E (with high Young's modulus in back panel and under-band) exhibited the lowest dynamic peak pressure increment (0.07 ± 0.01 kPa and 0.06 ± 0.01 kPa respectively) as shown in figure 4, *c*. This might have been because a high-modulus section would promote greater stretching in the adjacent areas, resulting in larger elongation, and thus higher pressure, which was also observed in previous research [7]. For Point c, only Bra E with a high Young's modulus in the under-band significantly increased the dynamic peak pressure; this effect could be attributed to the end-to-end structure of the under-band, which was weakly influenced by other parts.

The effects of elasticity distribution on compressive feeling

As shown in figure 5, the compressive feelings of Bra A ($2.20 \pm 0.10 \sim 2.72 \pm 0.13$), E ($1.93 \pm 0.14 \sim 2.83 \pm 0.15$) and F ($1.75 \pm 0.12 \sim 2.01 \pm 0.11$) were all below 3 at all four test points, indicating that the pressure is appropriate and acceptable, while that of Bra B (3.78 ± 0.26) and D (3.46 ± 0.29) at Point b, and Bra C at Point d (3.85 ± 0.18) exceeded 3, indicating that

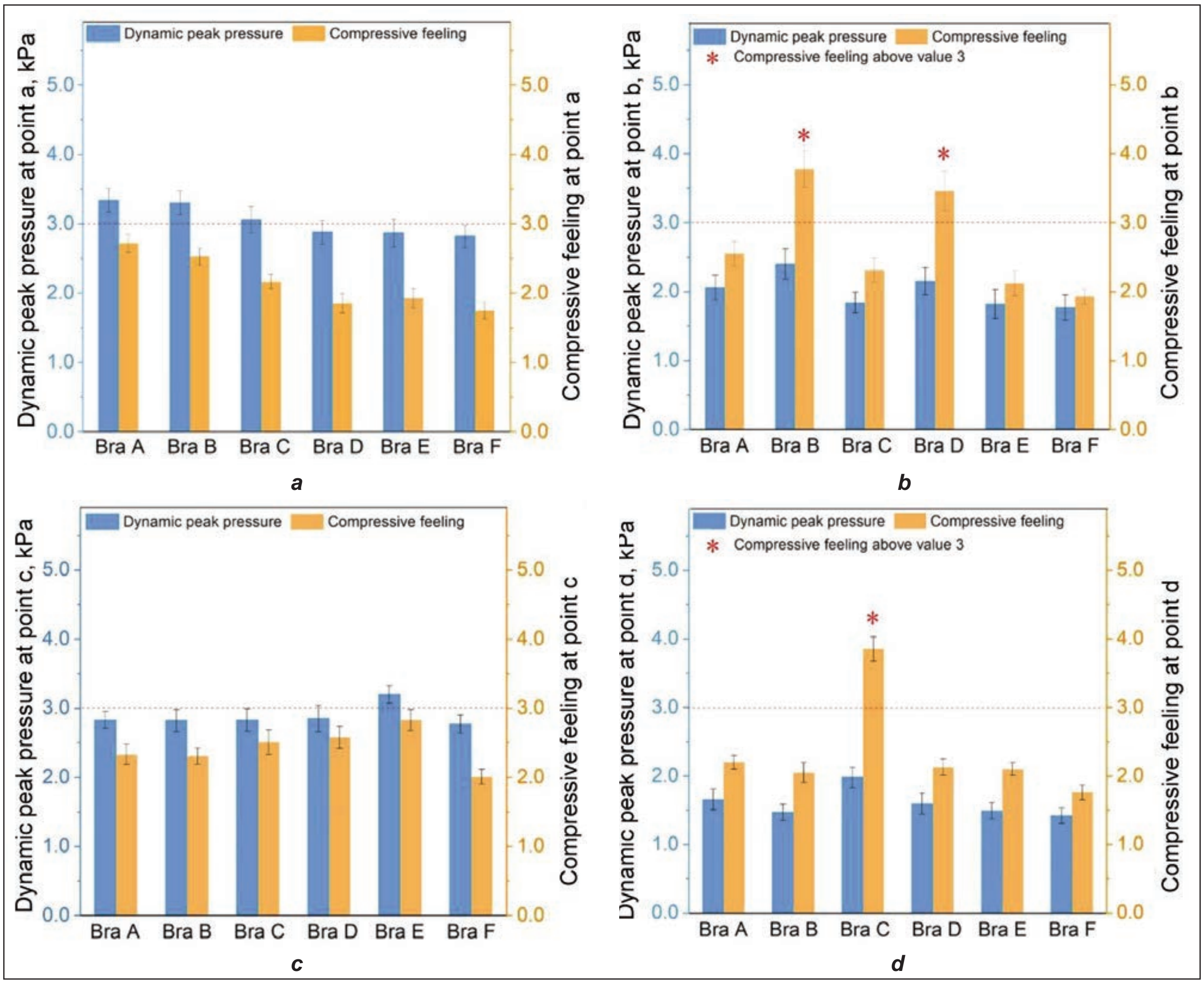


Fig. 5. The dynamic peak pressure and compressive feeling of six sports bras at: *a* – Point a; *b* – Point b; *c* – Point c; *d* – Point d

the pressure is excessively high and might contribute to discomfort. Therefore, although Bra A and E significantly increased the dynamic peak pressure at Point a, b, d (for Bra A), and Point c (for Bra E, as shown in figure 4, *a*), they would not induce pressure discomfort.

The results might have been due to the differences in pressure comfort thresholds (PCT) across body regions, which were also reported in previous researches [8], resulted from the differences in human anatomical structure, such as local shape, subcutaneous soft tissue properties and bone structure or the differences in body deformation under external pressure, which had been suggested closely related to the clothing pressure comfort [18]. The bone-next-to-skin areas (e.g., Point a and c) always exhibited a higher PCT, while the areas where remarkable fat accumulated always showed a lower PCT (e.g., Point d) [8]. In addition, a wider, thicker, and more curved upper back, the increased back pain, and discomfort in the levator scapulae muscle caused by the additional burden of the breasts observed in senior females [19] might contribute to a lower PCT in the upper scapular area (Point b).

Summarily, Bra A and E performed best, which significantly enhanced RBD without inducing pressure discomfort, accepting the third hypothesis. Bra C also effectively improved RBD; however, it exerted excessive pressure at point d, while Bra D significantly improved RBD in direction Z but led to excessive pressure at point b. Bra B showed no significant effect on RBD but generated excessive pressure at point B, resulting in pressure discomfort.

Consequently, the elasticity of applying high-Young's modulus fabric in front straps (Bra A) and under-band (Bra C) was suggested to optimise both RBD and pressure comfort for senior females.

CONCLUSION

This study provided novel information in optimising the breast support and pressure comfort performance of sports bras for senior females, by applying elasticity distribution in front strap, back strap, cup, back panel and under-band. The findings revealed that elasticity distribution significantly affected RBD, pressure distribution, and compressive feeling of senior females during the typical movement of square dancing, i.e., forwards-backwards stepping.

The effect on RBD varied with elasticity distributions and directions. Bra A, C, and E significantly improved RBD in all three directions ($P < 0.001$), Bra D only enhanced RBD in direction Z ($P < 0.001$), while Bra B showed no significant effect in any direction. The effect on pressure varied with the specific placement of the test point relative to the high-Young's modulus part of the sports bra. For Points a, b, and d, bras with high Young's modulus in the parts covering and adjacent to the test points generated higher pressure than the others, while for Point c, only Bra E with high Young's modulus in the under-band significantly raised the dynamic peak pressure. The compressive feelings of Bra A and E were all below 3 (neutral compressive feeling and the pressure is considered appropriate) at all four test points, while those of Bra B, C, and D exceeded 3 at certain test points. Comprehensively, the elasticity distributions of applying high-Young's modulus fabric in the front straps (Bra A) and under-band (Bra E) were ideal and typical, which significantly enhanced RBD without inducing discomfort, and were suggested to optimise both RBD and pressure comfort for senior females.

It is suggested that future research may include a wider range of Young's modulus, more elasticity distribution cases, test points, and more low-intensive activities to provide a comprehensive and in-depth understanding of the effects of elasticity distribution for senior females. Additionally, A large-scale experiment with stratified depth randomisation will be needed for future research to benefit more exercising senior females of different ages, body mass, breast morphology and breast size.

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