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The inter-connection of sports bra design attributes and elderly women's perceptions

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Abstract

As a sports facility category, a sports bra is regarded as an enabling technology garment with advanced functions and new cultural meanings. Women, particularly elderly women, are encouraged to wear a sports bra during physical activity because wearing a sports bra can not only prevent them from exercise-induced injuries but also increase the acceptance of their bodies. However, most studies usually targeted younger women. The requirements and expectations of elderly women on sports bras differ from younger individuals. Hence, this study aims to advance and explore the design demands, providing insights into age-friendly sports bra design by using more permeable physical and psychological boundaries based on conceptual frameworks. The sports bra evaluation words were extracted and calculated to construct the network. The appearance frequency of keywords, closeness centrality, betweenness centrality, and interconnection between every pair of words were illustrated and analyzed by using semantic-based network analysis. Network analysis deduced that the discomfort of sports bras was closely related with the support, tightness, cup design, and strap design. Beside, thermal management contributes significantly to the comfort. The outlook of a sports bra was associated with cup design. The Page-rank result showed that cup, tightness, hot, straps and quality were the top five important design attributes. The unobservable mechanisms underlying the keywords provide an alternative model, which can help to explore the key improvements for sports bra design.

Keywords: Sports bra, Elderly women, Network analysis, Semantic, Design, Requirements

Introduction

As a sports facility category, a sports bra is regarded as an enabling technology garment with advanced functions and new cultural meanings (Schultz, 2004). Women, particularly elderly women, are encouraged to wear a sports bra during physical activity because wearing a sports bra can not only prevent them from exercise-induced injuries but also increase the acceptance of their bodies (Bowles et al., 2012). Popular methods for sports bra evaluation and design focused on the biomechanical performance characterization objectively (Zhou & Ma, 2020; Zhou et al., 2022a, b). Quantitative analysis was conducted to improve the breast vibration control (Zhang et al., 2022), support (McGhee et al., 2013), comfort (Zhou et al., 2022a, b) and thermal management (Zhang

et al., 2021). It was well-documented that the breast discomfort and pain was significantly related to the magnitude of breast displacement. Although researches advocated the effectiveness through physical activity, only 32% of UK women using the sports bra during exercises (Bowles et al., 2008). This indicates that a good design of sports bra not just limited to the motion control. The design attributes for a sports bra usually involves many other variables, such as fit, appearance, support, shaping effect, etc. (Risius et al., 2014). Besides, the psychological demands are perceived as equally important that constructed by mental, social and behavioral aspects (Risius et al., 2012). With the bodily maintenance of the breast appearance, the confidence and liberation connected by sports bras bring women an active lifestyle (Risius et al., 2014).

The satisfaction of sports bra design depend on the extent to which one prioritizes requirements and individual physical and psychological conditions. These symptoms raise the question of what kinds of design features become more salient to satisfy their requirements of sports bras (Hsiao-Wecksler & Robinovitch, 2007). Furthermore, the key performance variables for the evaluation of sports bra physical and psychological effects are complexly interrelated and interacting (Brown et al., 2014). Isolation investigation of several functional variables fail to understand the evaluation variables of sports bra from the elderly women. Therefore, it is necessary to understand users' satisfaction through the complex action of various inter-related characteristics of sports bras. The understanding on those variables that are most satisfied or dissatisfied, and their interrelationship among each other provide organizational insights into the nature of the elderly women's requirements from both functional and emotional parts.

Although a variety of studies for the exploration of the satisfied sports bra design, the key efforts tend to control the kinematics and kinetics with specific targets, or aesthetic and comfort targeted with various selected sports bras. The breadth of key evaluation parameters and user needs for women are insufficient and incomprehensible. The correlation and interaction of variables need to be clearly illustrated rather than strictly following the prescribed study frameworks or specific procedures. Traditional questionnaire measurement was difficult to convey the emotional word accurately and present the multi-factor problem structurally (Gorea et al., 2020). The diversification of user needs was hard to explore based on scaling data. People make a decision usually based on unconsciously, subjective impressions of products (Hansen & Willemoes Rasmussen, 2022). Such features of impression can be built based on the emotional design, which translates the subjective demands into design criteria and solid product features. It is significant to note that the elderly women need design and sports bra evaluation parameters for sports bra design are lack of systematic organizations. On the other hand, Progress in this area of study also be limited by targeted users. Even the exponentially growing products designed for the younger women and the market tends to saturate, there is sparse information regarding the understanding of the elderly women's needs and well designed age-friendly sports bra to address their special physical and psychological demands. Influenced by the aging process, the elderly women have been out of body shapes, such as sagging breast, impaired spine curvature, deepening kyphosis and unattractive body appearance, which has the potential effect on their attitude towards exercise behavior, sports bra and social interactions (Morris et al., 2017). Similarly, once the elderly women are constructed by an ideal breast, side effects of the aging process

will be alleviated. However, the requirements and expectations of elderly women on sports bras differ from younger individuals.

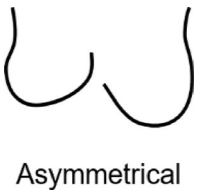
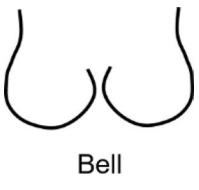
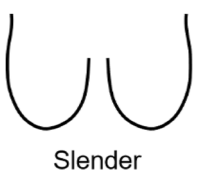
Hence, this study aims to advance explore the design needs and apply needs for providing insights into age-friendly sports bra design by using more permeable physical and psychological boundaries based on theoretical networks. The sports bra evaluation words were extracted and analyzed. The frequency of appearance of keywords, closeness centrality, betweenness centrality, and interconnection between every pair of words was illustrated and analyzed by using semantic-based network analysis. The influential parameters that have strong connections with sports bra satisfaction can be identified. This study focused on the evaluation of the emotional satisfaction of elderly women on a sports bra to determine their functional and emotional needs for a sports bra. The unobservable mechanisms underlying the keywords provide an alternative model, which can help to explore the key improvements for sports bra design. Further research of designing sports bras can be warranted based on systematic and scientific evidence to ensure the design criteria can fulfill both functional and comfortable.

Methods

Participants

Sixty older female aged from 58 to 66 years with breast size ranging from 80C to 95D were selected to participant in this study. The detailed body profile of participants were shown in Table 1. Participants were Chinese-based females, had experienced normal breast-feeding history, no breast-related surgery history nor undergone any clinic breast-related treatment. All participants volunteered to participant this study, and also have written informed consent about the study aims and experimental procedures prior to

Table 1 Detailed body profile of participants

Variable	Mean SD	Breast shape	Number
Age	62 ± 4.09	 Asymmetrical	8/60
Body mass index	24.98 ± 2.57	 Bell	7/60
Underband size	83.33 ± 3.92	 Slender	45/60
Cup size	C (51/60) D (9/60)		

experiment start. Ethical approval was given for the study according to university ethical guidelines.

Bra samples. Eight selected sports bra has various designs in terms of pattern, material, color, and structure. Eight commercialized sports bras were selected for the experiment: No.1 Nike Women's Zip Dri-Fit medium support sports bra, front closure design allows the elderly easily dress and undress sports bra by themselves. No.2 Nike Rival Training Bra has adjustable sliders on the racerback to provide a large range of motions. No.3 Under Armour Eclipse High-impact sports bra made of smooth and permeable materials can have a good thermal performance and touch sense for users. No.4 Gourami low support sports bra designed with elastic materials makes it stretchable. No.5 Wacoal Coolmax Contour Underwire sports bra designed with wide shoulder straps and wide back underband design are comfortable and supportive. No.6 OYSHO low supportive yoga bra featured its fashionable style that could improve users' confidence. No.7 L'URV encapsulated medium support sports bra has a hip-length shirt that can cover the fatty shape of wears and its slim cut in a three-dimensional way also can have a good shaping effect. No.8 lululemon made of firm fabrics seamlessly can offer a good touch and strong support. Each sports bra has its design features and focuses. All design attributes work together and interact with one another attribute aiming to provide good functions for wear. The detailed information and illustration are shown in Table 2. The body measurement for participants was conducted at first, then based on their breast size, the right size bra samples with random order were selected. Assistant was required to help with the adjustment of bra fitting. Each participant was asked to wear the eight pieces of sports bras for wear trial.

Questionnaire and word determination

Participants were invited to give their comments on their perceptions, preferences, requirements, and anticipations on the sports bra fitting, aesthetic, and functional aspects. The interview conformed to the semi-structured open answer mode. During the process, the research assistants tried to relax the participants and let them feel free to give comments according to several questions. The answers were recorded and then transcribed and translated into transcripts. Under consideration of the confusion that occurs during using the second language, double-back translation checks were adopted.

The question was selected based on bra-related design features and previous literature. The sports bra components are similar but can be designed with different parameters. Specifically, a sports bra usually includes the cup, underband, straps, wing, gore, back panel, and closure. To fulfill different demands, different parameters should be matched. It was reported that molded cups can limit breast motion (Bowles et al., 2012), fabric with horizontal elasticity should be used for chest expansion during respiration (Page & Steele, 1999), or fabric with good thermal transportation can provide a cool feeling (Huang et al., 2021). Hence, the first six questions were proposed. Previous studies indicated that the bra design attributes of primary importance to users were tightness, shaping effect, comfort, fit, and pattern design (Risius et al., 2012, 2014). As those attributes were perceived as being necessary for the satisfaction of a sports bra, the following five questions were proposed. The questions are as follows:

Table 2 Features of eight selected commercial sports bra

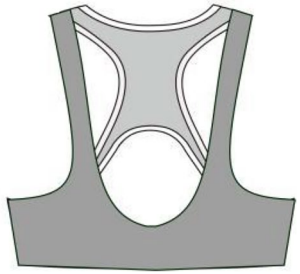
No	Front view	Back view	No	Front view	Back view
1			2		
Bra impact	Medium support		Bra impact	High support	
Type	Encapsulation			Encapsulation	
Back design	Double racerback		Back design	Adjustable racerback	
Features	Zip on the center front, padded bra, shoulder straps with built-in stabilizers		Features	Breathable fabrics with high moisture-wicking, mold cups, wireless underwire, back closure	
Materials	Body fabric and straps: 75% nylon, 25% elastane Back panel: 78% polyester, 22% elastane		Materials	Body fabric: 75% nylon, 25% spandex Center back panel: 78% polyester, 22% spandex	
Brand	Nike®, Inc		Brand	Nike®, Inc	
Serial No	858,430		Serial No	805,553	

Table 2 (continued)

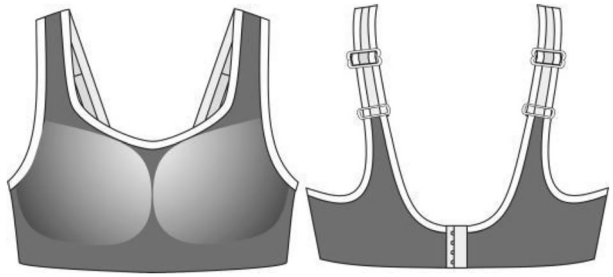
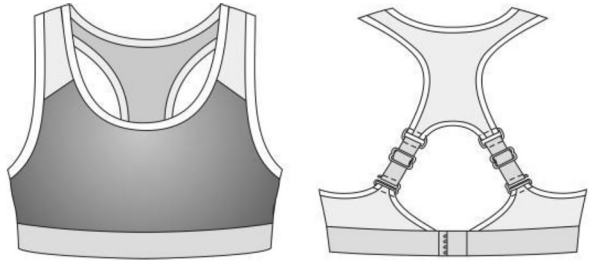
No	Front view	Back view	No	Front view	Back view
3			4		
Bra impact	High support		Bra impact	Low support	
Type	Encapsulation		Type	Compression	
Back design	Back closure with adjustable straps		Back design	Racerback	
Features	Soft and breathable mesh lining Smooth touched fabrics Wider shoulder straps		Features	Built-in bra with removable padding, scoop neck, mesh for whole back design	
Materials	Body fabric: 89% nylon, 11% elastane Mesh fabric: 60% elastane, 40% nylon		Materials	Body fabric: 82% Nylon, 18% Elastane Mesh fabric: 67% Nylon, 33% Elastane	
Brand	Under Armour®, Inc		Brand	Gourami® Concord China Ltd	
Serial No	1,293,253,693		Serial No	GAL-162-BRN-054	

Table 2 (continued)

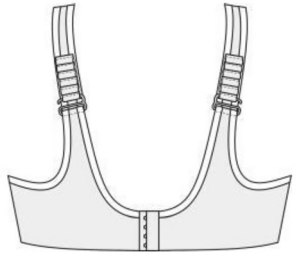
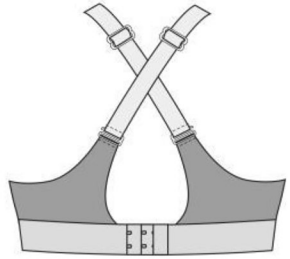
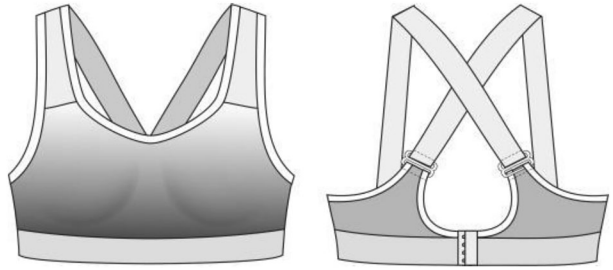
No	Front view	Back view	No	Front view	Back view
5			6		
Bra impact	High support		Bra impact	Low support	
Type	Encapsulation		Type	Encapsulation	
Back design	Back closure with adjustable straps		Back design	Back closure with adjustable straps	
Features	Wider straps, padded cups with underwire, wider back band		Features	Asymmetric stylish design	
Materials	80% nylon, 20% spandex		Materials	Body fabric: 79% polyester, 21% elastane, Mesh fabric: 79% polyamide, 21% elastane	
Brand	Wacoal® H.K. Co. Ltd		Brand	OYSHO ESPAÑA, S.A	
Serial No	853,209		Serial No	2977/974/611	

Table 2 (continued)

No	Front view	Back view	No	Front view	Back view
7			8		
Bra impact	Medium support		Bra impact	Medium support	
Type	Encapsulation		Type	Encapsulation	
Back design	Cross back design		Back design	Cross back keyhole design	
Features	Hip length, compression fabrication, cross-back design, removable cups, trimmed pattern		Features	Lightweight, breathable build-in cups, bonded underband, high modulus fabric	
Materials	71% Nylon, 29% Lycra		Materials	Body fabric: 56% Nylon, 44% Lycra® elastane Cup lining: 80% Polyester, 20% Elastane	
Brand	L'URV		Brand	lululemon® HK Limited	
Serial No	LGFI025101031M		Serial No	SKU: LW2AVSS	

1. Are you satisfied with the straps? If not, can you describe the problems?
2. Are you satisfied with the underband? If not, can you describe the problems?
3. What do you think about the fabric and materials of the sports bra?
4. Are you satisfied with the cup design?
5. Are you satisfied with the front design?
6. Are you satisfied with the back design?
7. What do you think about the tightness arrangement of the sports bra?
8. What do you think about the shaping effect of the sports bra?
9. Are you satisfied with the overall bra comfort?
10. Are you satisfied with the overall bra fit?
11. What do you think about the pattern design of the sports bra?
12. Do you have something want to share after the wear trial?

According to the questionnaire items, the organized impressions were comprised of 18 factors, including 74 words. The factors and words were as follows: Sports bra (lingerie, bra, brassiere), Comfort, Cup (mold, mold, molded), Discomfort (pain, itchy), Pressure, Straps, Fabric (material, textile, lace, mesh, embroideries, embroidery, accessory, accessories), Back, Openings (eyes, hook, closure), Support (supportive, supporting), Fit, Pattern (trim, seam, sewing, construction, configuration), Motion (bounce, vibration), Quality, Tactile (soft, smooth, hand), Tightness (loose, looseness, sliding, unattached, loosen, gap, slip, tight, tightness, dig, digging, denseness, restricted, restrict, small), Hot (thermal, sweat, permeable, permeability), Outlook (attractive, willing, pleasure, young, confident, confidence).

Semantic-based network analysis (SNT) is a kind of invaluable tool for the systematic assessment of relationships and structures of the network, which has increasingly been used in many disciplines such as supply chain management (Kim et al., 2011), and social behavior psychology (Berg et al., 2020). Network analysis of the design attributes and users' perceptions was conducted in Python (Version 3.8.13). Pycharm 2021.2.1 software (JetBrains, Prague, Czech Republic) was used to code the model of Network Analysis, which was introduced to identify the design attributes and users' perceptions. The key included packages are python (Version 3.8.13), networks (Version 2.8.6) (Hagberg, 2008), and jieba (Version 0.42.1). The structure of the network consists of nodes and edges. Any hashable object as the nodes are linked by edges. The edge data were expressed by number (edge weights) which represents the partial correlations between two nodes (Epskamp & Fried, 2018). The network can be statistically characterized by several indexes, including closeness centrality, betweenness centrality, and clustering coefficient, and can be visualized by the shortest distance and relative locations of nodes. Specifically, closeness centrality represents the hardness of one node reaching another, which can be calculated by the inverse of the mean of all other junction distances. Betweenness represents the shortest path between each pair of nodes. The clustering coefficient represents the number of triangles in one network (Epskamp & Fried, 2018). PageRank algorithm was applied in this study to measure the relative importance of an element or a word in the collection range by assigning weight. Initially, it was used by web pages, which reflect the probability of something randomly happening by outputting a probability distribution (Haveliwala, 2002). Community detection was determined

by the spinglass algorithm (Cramer et al., 2010) through igraph (Csardi & Nepuze, 2006). By using SNT, this study aims to understand the structural connection between the sports bra design attributes and older women's perceptions. Herein, the keyword was set as a node while the connection between these nodes was an edge. The network visualization was built by different locations of nodes through the centrality index. The relationship between words was obtained by a matrix, and all connections among all words were initialized through a one-way matrix (18×18). Structural equivalence in network evaluation was based on the frequency index of the simultaneously co-occurred words. The following was to find the communities based on their similarity. The inter-relationship among every pair of keywords can be determined by the iteration frequency in the matrix. The betweenness centrality and closeness centrality decide the distance between each word and the center of the network, finally, the entire network can be finalized.

Results

The sports bra performance evaluated by the elderly women was constructed by SNT. The network among selected keywords of design attributes and perceptions was shown in Fig. 1. The frequency division was set by ~ 30, 30 ~ 100, 100 ~ 200, > 200. Exploration at the word level provides the general distribution and interrelationship of keywords. As shown in Fig. 1, the strongest links were donated with green lines, stronger links were donated with yellow lines, the medium strong links were represented as orange, less strong links were represented as blue lines, and the lowest strong links were donated with purple lines. The distance among nodes (keywords) represents their correlation levels (Fig. 2). The yellow circle under each word stands for the frequency level of the words' appearance.

The network structure clearly shows the interrelationship among keywords. It can be found that comfort-motion, comfort-cup, and straps-tightness were closely interrelated.

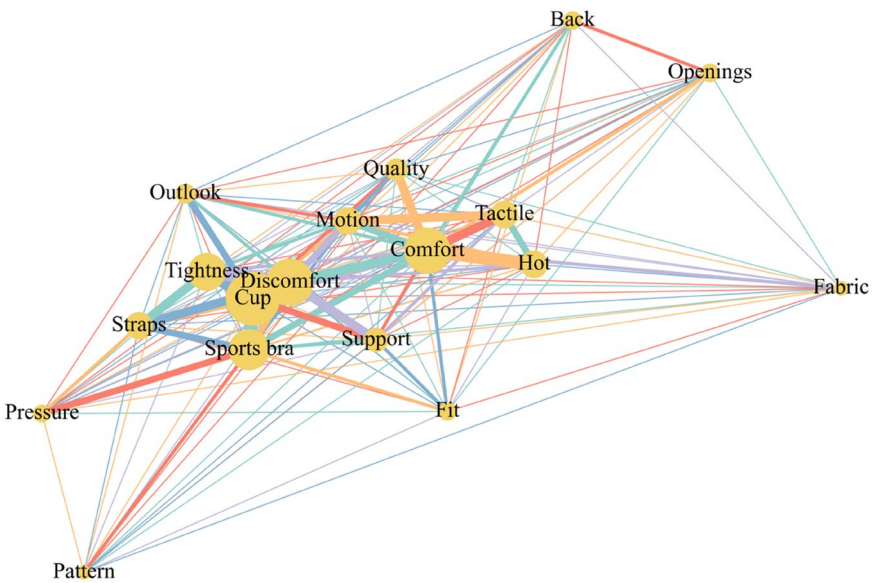


Fig. 1 Networks of design attributes and perceptions of the elderly women for a sports bra. The links among keywords were illustrated, in the order of largest to lowest, green, yellow, orange, blue, and purple. The distance among nodes (keywords) represents their closeness level

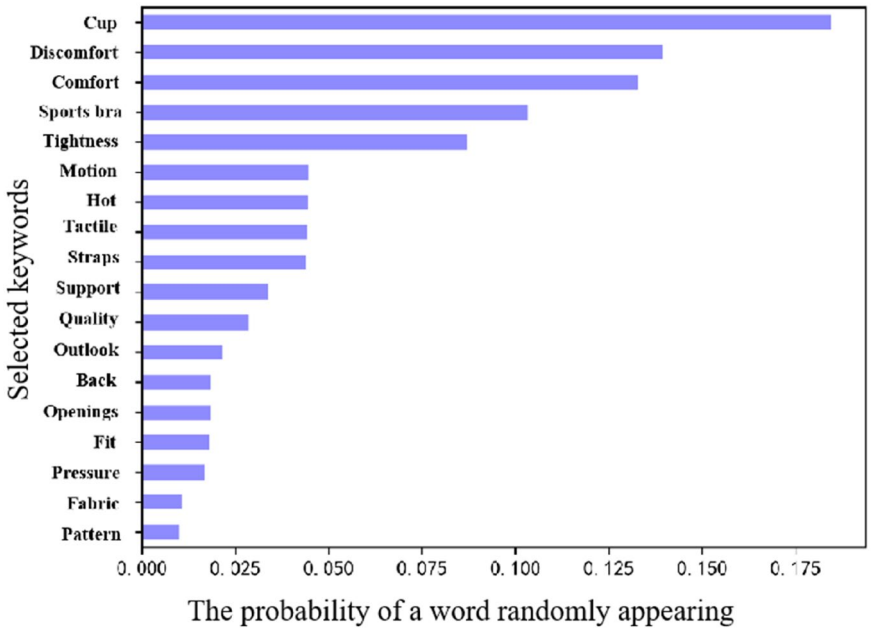


Fig. 2 Importance ranking of keywords by page-rank algorithm

Following were comfort-hot, motion-tactile, and comfort-quality, which were slightly less closely than the previous pairs. The next closeness level was sports bra-pressure, cup-support, and comfort-tactile.

Page-Rank value ranked the important keywords in the order of greatest to least. For the design attributes, the most important words were cup, tightness, hot, straps, and quality. For the perceptions, the most important words were discomfort, comfort, motion, tactile, and support. Whereas, pattern, fabric, openings, back, and outlook were not such important design attributes as analyzed by SNT. Fit and pressure were the least important words perceived by the senior women.

Community detection was performed by the Louvain heuristices algothrim (Blondel et al., 2008). The resolution for the best community partition was set as 0.8. Three communities were detected and presented in Fig. 3. One community is a sports bra, cup, discomfort, pressure, straps, support, pattern, and tightness; and the other community is comfort, fabric, back, openings, fit, motion, quality, tactile, hot, and outlook.

The correlation coefficient explores the importance of the keywords based on the item level. The result of the correlation coefficient (CC) was shown in Fig. 4. The horizontal direction represents the y-axis, while the vertical direction represents the x-axis. The CC was calculated by dividing the co-occur number of the x and y in one sentence by the number of the sentence that just included x (or y). Straps had the highest strength value for a sports bra (0.67), cup (0.67), and pressure (0.33), which means straps had a more significant influence on a sports bra, cup, and pressure. Comfort had significant influence on fabric (0.33), fit (0.28), tactile (0.27), and hot (0.58). It also can be noted that the cup design was the strongest influence on a sports bra (0.22), discomfort (0.23), straps (0.67), tightness (0.34), and discomfort (0.30) were strongest for support. Cup, outlook, and motion had the least influence on other words. For all keywords on the y-axis, motion and outlook were obviously the words with the lowest correlation in

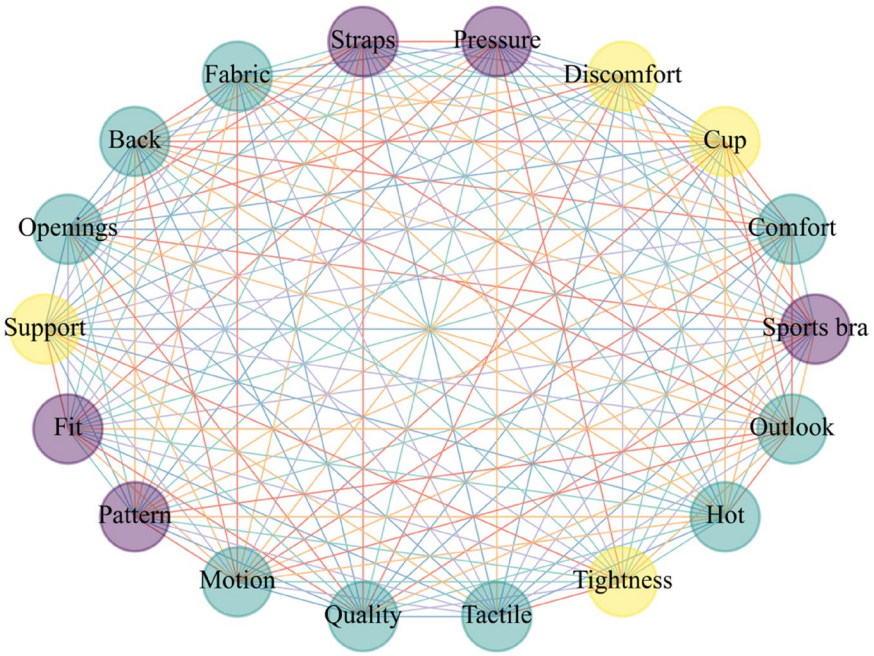


Fig. 3 Community detection for keywords. Keywords were clustered into two communities, one community was in purple color, the other one was in yellow color

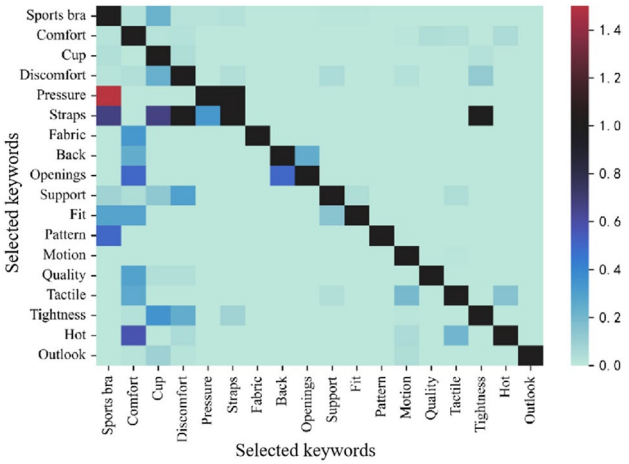


Fig. 4 Heatmap of the correlation coefficient among keywords. Comparison of strength values among keywords. Keyword pairs with stronger relationship were represented as darker color as the right contour bar indicated

the network, indicating that motion and outlook had the least correlation with other keywords.

Discussion

The purpose of this study was to structurally explore and understand the senior women's perceptions of sports bra design attitude. By using SNT, the network of keywords derived from design-related parameters and perception-related feelings was constructed.

The keywords were clustered into several communities based on an examination of the relationship on the words' level. Results from this study can help to fill the gap of unstructured and limited multi-factorial relationship analysis of sports bra performance evaluation. Results from the network analysis show that the closest relationships were the comfort-motion, comfort-cup, straps-tightness, then comfort-hot, motion-tactile, and comfort-quality, followed by bra-pressure, cup-support, and comfort-tactile. Three communities were detected, and the unobservable mechanism underlying the keywords can help to target the core of the sports bra design or users' perceptions. The page-rank value ranked all keywords from the most important to the least important. Lastly, in pair words, a comparison of the strength values was calculated. All the information contributed to the refinement and development of sports bra design, which is important for the adaptability and acceptability of senior women.

Indicated by the network analysis, comfort had the closest relationship with other words, including motion, cup, quality, and tactile. This result was consistent with the previous result. The stability of a sports bra refers to the ability to hold breasts in place, or not ride up, which was perceived as an important variable of comfort and support (Filipe et al., 2015). Most older women suffer from breast sagging problems (Coltman et al., 2017), it is not only a sign of increasing age (Sukuma, 2007), but also a sign of increasing need for care. It is reported that almost 70% of female was dissatisfied and embarrassed with their breast appearance, which can result in several series outcomes including distress, depression, a reluctance to participate the physical activity, lower self-confidence, and even an unhealthy lifestyle (Risius et al., 2014). To keep the appearance attractive and feminine whilst avoid to feeling embarrassed, the attitude to the sports bra shaping effect are anticipated from squeezing together, shoving forward, plumper to flattened down to make breast illusion little (Schultz, 2004). Cup was believed as one of the most effective parts to uplift the breast and shape breast into an attractive appearance. For the quality, it was reported as the main reason for older women purchasing which piece of sports bra. The bra should be capable of washability. After a period of duration, the sports bra can maintain its functions. For the tactile, soft, smooth and hand feelings were involved in the tactile category. This perception was reported as the most commonly cited theme, stating no specific fabric type, but the smooth fabric should be comfortable (Risius et al., 2012). All results have the literature support, but this study firstly combined and rank their importance. Ranked by the PR algorithms, it indicated the importance of perceptions and design attributes. Tightness ranked the first important design attribute, the sports bra should be neither too loose nor too tight. The tight design will cause negative health problems, such as blood circulation, breathing difficulty, etc. (Liu et al., 2012). The comfort range for pressure should be less than 60 g cm-2 (Zhang et al., 2002). Straps design ranked the first among users complaining about anecdotal evidence. The wider and non-adjustable straps were preferred designs for more breast support and breast motion control (Coltman et al., 2015). But in this study, straps were not proved as the most important design attribute. Prior to strap design, motion and hot were more important. Several attempts have been tried to limit the breast motion, such as high neckline design and wide wing. By compressing breasts onto the torso, the breast moment can be decreased, accordingly to reduce the loading on anatomical tissues (Zhang et al., 2021). It has been recommended that sports bra with

good motion control should be equipped with short vest style, high neckline, cross back design, and without gore, underwire, inserted padding (Zhou et al., 2013).

According to the community detection result, the discomfort, cup, tightness, support were clustered in one community. Those words represents older women were discomfort, which they were not satisfied with the sports bras' tightness, support and cup design. As for the community that includes comfort, outlook, hot, tactile, quality, motion, openings, back and fabric, it represents older women were comfort. Hence, it can be indicated that the older women were satisfied within the same community. Last community included sports bra, straps, pressure, fit, pattern. When talks about sports bra, the first thought comes into mind might be straps, pressure, fit and pattern. Up to 85% of females wear the wrong size bra because of the poor knowledge of body measurement and bra fitting (White & Scurr, 2012). Hence, the focuses of sports bra design were straps, pressure, fit and pattern. The key to alleviate discomfort was cup, tightness, support.

The correlation coefficient for each pair of words provided further insights into the interaction among those keywords, emphasizing how much of one influence the other one. This results revealed the most targeted design attributes to the perceptions or to the other design attributes. It is no doubt that pressure was the most important indicator to the tightness. Whereas had little influence on fabric, back, openings, quality, tactile, tightness, hot and outlook. Cup, outlook, and motion had the least influence on other words. When design for a specific usage or targeted user group, this CC can be helpful to easily find the most related parameters and make product development.

Conclusions

To structurally understand the particular requirements for senior women, eight commercial sports bras with varied designs in terms of structure, pattern, color, material, and structure were selected. Sports bra performance was evaluated by 60 participating females aged between 58 to 66 years with 80C to 95D cup sizes. Wear trial and semi-structured interviews were conducted and analyzed by using semantic-based network analysis. 74 words consisting of none and adjective words were included. The theoretical network was built and the interrelationship among design attributes and user perceptions was visualized. It can be found that comfort-motion, comfort-cup, and straps-tightness were closely interrelated. For the design attributes, the most important words for the senior women's attitude to sports bras were cup, tightness, hot, straps, and quality. For the wearing perceptions, the most important words were discomfort, comfort, motion, tactile, and support. With regards to the CC among words, straps had the highest strength value for a sports bra, cup, and pressure. Comfort had significant influence on fabric, fit, tactile, and hot. Cup, outlook, and motion had the least influence on other words. The results indicated that elderly women also pursue the ideal body appearance, and in the meanwhile, free movement was highly related to comfort. Those findings provided further insights into the selection of the most statistically influential design attribute effects on elderly women's perceptions. It also will be helpful to easily find the most related parameters and make product development.

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Author contributions
JZ, JZ and QEL were responsible for the whole experimental design, structure construction and data processing. AW was responsible for the survey data collection and data cleaning. QM was responsible for the data processing. JZ and JZ were responsible for drafting the manuscript. JY was responsible for revising the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics and consent
This research was conducted under the approval and supervision of XX University Institutional Review Board (IRB Approval No:YYY-ZZZ-QQQ) regarding ethical issues including consent to participate. https://fashionandtextiles.springeropen.com/submissionguidelines/preparing-your-manuscript/research.

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References

Blondel, V. D., Guillaume, J. L., Lambiotte, R., & Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of Statistical Mechanics: Theory and Experiment, 2008*(10), 10008. https://doi.org/10.1088/1742-5468/2008/10/P10008

Bowles, K. A., Steele, J. R., & Munro, B. (2008). What are the breast support choices of Australian women during physical activity? *British Journal of Sports Medicine, 42*(8), 670–673. https://doi.org/10.1136/bjsm.2008.046219

Bowles, K. A., Steele, J. R., & Munro, B. J. (2012). Features of sports bras that deter their use by Australian women. *Journal of Science and Medicine in Sport, 15*(3), 195–200. https://doi.org/10.1016/j.jsams.2011.11.248

Brown, N., White, J., Brasher, A., & Scurr, J. (2014). An investigation into breast support and sports bra use in female runners of the 2012 London Marathon. *Journal of Sports Sciences, 32*(9), 801–809. https://doi.org/10.1080/02640414.2013.844348

Coltman, C. E., McGhee, D. E., & Steele, J. R. (2015). Bra strap orientations and designs to minimise bra strap discomfort and pressure during sport and exercise in women with large breasts. *Sports Medicine-Open, 1*(1), 1–8. https://doi.org/10.1186/s40798-015-0014-z

Coltman, C. E., Steele, J. R., & McGhee, D. E. (2017). Breast volume is affected by body mass index but not age. *Ergonomics, 60*(11), 1576–1585. https://doi.org/10.1080/00140139.2017.1330968

Cramer, A. O., Waldorp, L. J., Van Der Maas, H. L., & Borsboom, D. (2010). Comorbidity: A network perspective. *Behavioral and Brain Sciences, 33*(2–3), 137–150. https://doi.org/10.1017/S0140525X09991567

Csardi, G., & Nepusz, T. (2006). The igraph software package for complex network research. *InterJournal, Complex Systems, 1695*(5), 1–9.

Epskamp, S., & Fried, E. I. (2018). A tutorial on regularized partial correlation networks. *Psychological Methods, 23*(4), 617. https://doi.org/10.1037/met0000167

Filipe, A. B., Carvalho, C., Montagna, G., & Freire, J. (2015). The fitting of plus size bra for middle aged women. *Procedia Manufacturing, 3*, 6393–6399. https://doi.org/10.1016/j.promfg.2015.07.968

Gorea, A., Baytar, F., & Sanders, E. A. (2020). Experimental design and evaluation of a moisture responsive sports bra. *Fashion and Textiles, 7*(1), 1–21. https://doi.org/10.1186/s40691-020-00209-6

Hagberg, A., Swart, P., & S Chult, D. (2008). *Exploring network structure, dynamics, and function using NetworkX* (No. LA-UR-08–05495; LA-UR-08–5495). Los Alamos National Laboratory, https://www.osti.gov/servlets/purl/960616.

Hansen, S. T., & Willemoes Rasmussen, L. A. (2022). "At least there is something in my bra": A qualitative study of women's experiences with oncoplastic breast surgery. *Journal of Advanced Nursing, 78*(10), 3304–3319. https://doi.org/10.1111/jan.15309

Haveliwala, T. H. (2002, May). Topic-sensitive pagerank. In *Proceedings of the 11th international conference on World Wide Web* (pp. 517–526). https://doi.org/10.1145/511446.511513
Hsiao-Wecksler, E. T., & Robinovitch, S. N. (2007). The effect of step length on young and elderly women's ability to recover balance. *Clinical Biomechanics, 22*(5), 574–580. https://doi.org/10.1016/j.clinbiomech.2007.01.013
Huang, G., Wei, X., Gu, Y., Kang, Z., Lao, L., Li, L., Fan, J., & Shou, D. (2021). Heterogeneously engineered porous media for directional and asymmetric liquid transport. *Cell Reports Physical Science*. https://doi.org/10.1016/j.xcrp.2021.100710
Kim, Y., Choi, T. Y., Yan, T., & Dooley, K. (2011). Structural investigation of supply networks: A social network analysis approach. *Journal of Operations Management, 29*(3), 194–211. https://doi.org/10.1016/j.jom.2010.11.001
Liu, H., Chen, D., Wei, Q., & Pan, R. (2013). An investigation into the bust girth range of pressure comfort garment based on elastic sports vest. Journal of the Textile Institute, 104(2), 223–230.
McGhee, D. E., Steele, J. R., Zealey, W. J., & Takacs, G. J. (2013). Bra–breast forces generated in women with large breasts while standing and during treadmill running: Implications for sports bra design. *Applied Ergonomics, 44*(1), 112–118. https://doi.org/10.1016/j.apergo.2012.05.006
Morris, K., Park, J., & Sarkar, A. (2017). Development of a nursing sports bra for physically active breastfeeding women through user-centered design. *Clothing and Textiles Research Journal, 35*(4), 290–306. https://doi.org/10.1177/0887302X17722858
Page, K. A., & Steele, J. R. (1999). Breast motion and sports brassiere design. *Sports Medicine, 27*(4), 205–211. https://doi.org/10.2165/00007256-199927040-00001
Risius, D., Thelwell, R., Wagstaff, C., & Scurr, J. (2012). Influential factors of bra purchasing in older women. *Journal of Fashion Marketing and Management: An International Journal., 16*(3), 366–380. https://doi.org/10.1108/13612021211246099
Risius, D., Thelwell, R., Wagstaff, C. R., & Scurr, J. (2014). The influence of ageing on bra preferences and self-perception of breasts among mature women. *European Journal of Ageing, 11*(3), 233–240. https://doi.org/10.1007/s10433-014-0310-3
Schultz, J. (2004). Discipline and push-up: Female bodies, femininity, and sexuality in popular representations of sports bras. *Sociology of Sport Journal, 21*(2), 185–205. https://doi.org/10.1123/ssj.21.2.185
Sukumar, S. (2007). The bra and the Indian woman's notion of sexuality. *Journal of Creative Communications, 2*(3), 267–278. https://doi.org/10.1177/097325860700200301
Van den Berg, J. W., Smid, W., Kossakowski, J. J., van Beek, D., Borsboom, D., Janssen, E., & Gijs, L. (2020). The application of network analysis to dynamic risk factors in adult male sex offenders. *Clinical Psychological Science, 8*(3), 539–554. https://doi.org/10.1177/2167702620901720
White, J., & Scurr, J. (2012). Evaluation of professional bra fitting criteria for bra selection and fitting in the UK. *Ergonomics, 55*(6), 704–711. https://doi.org/10.1080/00140139.2011.647096
Yanmei, L., Weiwei, Z., Fan, J., & Qingyun, H. (2014). Study on clothing pressure distribution of calf based on finite element method. *The Journal of the Textile Institute, 105*(9), 955–961. https://doi.org/10.1080/00405000.2013.865883
Zou, C., Lao, L., Chen, Q., Fan, J., & Shou, D. (2021). Nature-inspired moisture management fabric for unidirectional liquid transport and surface repellence and resistance. *Energy and Buildings, 248*, 111203. https://doi.org/10.1016/j.enbuild.2021.111203
Zhang, J., Lau, N. M., Sun, Y., Yip, J., Yick, K. L., Yu, W., & Chen, J. (2022). Non-linear finite element model established on pectoralis major muscle to investigate large breast motions of senior women for bra design. *Textile Research Journal, 92*(19–20), 3511–3521. https://doi.org/10.1177/00405175221075049
Zhang, S., Yick, K. L., Yip, J., Yu, W., & Tang, K. P. M. (2021a). An understanding of bra design features to improve bra fit and design for older Chinese women. *Textile Research Journal, 91*(3–4), 406–420. https://doi.org/10.1177/0040517520944253
Zhang, X., Chao, X., Lou, L., Fan, J., Chen, Q., Li, B., Ye, L., & Shou, D. (2021b). Personal thermal management by thermally conductive composites: A review. *Composites Communications, 23*, 100595. https://doi.org/10.1016/j.coco.2020.100595
Zhang, X., Yeung, K. W., & Li, Y. (2002). Numerical simulation of 3D dynamic garment pressure. *Textile Research Journal, 72*(3), 245–252. https://doi.org/10.1177/004051750207200311
Zhou, J., Yu, W., & Ng, S. P. (2013). Identifying effective design features of commercial sports bras. *Textile Research Journal, 83*(14), 1500–1513. https://doi.org/10.1177/0040517512464289
Zhou, J., & Ma, Q. (2020). Establishing a Genetic Algorithm-Back Propagation model to predict the pressure of girdles and to determine the model function. *Textile Research Journal, 90*(21–22), 2564–2578. https://doi.org/10.1177/0040517520922947
Zhou, J., Chen, J., Lau, N., Mao, Q., Gong, Z., Liu, Y., Yip, J., Yu, W., & Zhang, J. (2022a). A hybrid forecasting model for ageing breast deformation during yoga practice. *Textile Research Journal, 92*(7–8), 974–984. https://doi.org/10.1177/00405175211040867
Zhou, J., Mao, Q., Zhang, J., Lau, N. M., & Chen, J. (2022b). Selection of breast features for young women in northwestern China based on the random forest algorithm. *Textile Research Journal, 92*(7–8), 957–973. https://doi.org/10.1177/00405175211040869

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