

Assessing User Needs of Senior Women during Yoga Exercises to Optimize the Design Criteria of Sports Bras

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Given the arising burdens in social, economic and healthcare aspects due to the ageing population, senior women are encouraged to do more exercises in order to stay active. However, they are unwilling to do so due to various physical and psychological barriers. During the ageing process, the overall body shape has significant changes and breast becomes sagging. The design of sportswear could be one of the major factors recovering their motivation and confidence during social activities. In this study, questionnaire and field experiments were conducted to investigate the influence of sportswear on senior women. By analyzing the results, the needs on sports bra were primarily determined. Coupled with the results of biomechanical analysis from motion tests, the breast deformation during yoga poses was analyzed. The questionnaire shows that senior women mainly focused on the support and comfort of sports bras no matter how long their yoga practice history. Following are the "easy to wear on and take off" and "more coverage such as long shirt design and higher neckline design". From motion analysis, the breast deformation was changing in a large range when doing Warrior I and Warrior II yoga poses. To address the needs, sports bra design in terms of fabric, elastics, and over 10 features of construction were determined. As a result, the main purpose of this study suggests the design criteria on the optimization of sports bra which can fulfill the needs of physical and psychological for senior women.

Keywords: *senior women; exercise behaviour; sports bra; design criteria*

1 Introduction

The ageing population is one of the most common phenomena worldwide, which brings some formidable challenges on social, economic and healthcare (Cheng, Lum, Lam, & Fung, 2013). Response to those challenges arising from the ageing population, senior individuals are encouraged to be more physically active. Among those low-intensity physical activities, yoga is a very popular and age-friendly choose for senior women because yoga lacks the age restraints. It is well-known that yoga has versatile poses and different available levels for practitioners with a different level of physical conditions. Regular yoga practice can not only improve physical functions such as muscle strength, body balance and metabolic system but also benefits for psychological health to alleviate stress, late-life depression and nervous. (Banks, 2011; Chen et al., 2009; Roland, Jakobi, & Jones, 2011)

It is well documented that physical activity is essential for older adults which can be worked as a mechanism to improve the quality of late-life for achieving successful ageing. (Berlin, Kruger, & Klenosky, 2018) However, despite the senior individuals possess more leisure time after retirement, the amounts and rates of engagement in physical activities have a trend of declining as age increases. (Zuzanek, Robinson, & Iwasaki, 1998)

2 Literature review

The reason for senior adults having sedentary behaviour may be concluded into two determinants: one is the elderly is lack of confidence to perform the exercise (Chogahara, 1999; O'Brien Cousins, 1998) and the other is the declining health condition. The senior individuals view themselves as a group who are vulnerable to injury during exercise, besides, they usually magnify the risks arising from physical activity. Those are usually deemed as the barriers to engage the older adults in exercise. (Calnan & Johnson; Chou, Hwang, & Wu, 2012) Some researchers in the exercise psychology field have developed a lot of psychological theories and concepts to explain the exercise-related behaviours of the older adults, such as what motivates them to initiate physical activity and how to maintain that activity. Fisher had used the Information-Behavioural Skills (IMB) models to analyze the arena of health-related behaviours influenced by social factor and psychological factors. In his model, it is asserted that information, motivation, and behavioural skills are the fundamental determinants of initiating behaviours. (Fisher, Fisher, & Harman, 2003) Bandura's social cognitive theory (SCT) as the most convincing theory is often used to understand and predict the exercise behaviour of the elderly. It consists of four cognitive constructs: self-efficacy, motivations, goals, environments or social influents and outcome expectations. (Bandura, 1986) Then, O'Brien Cousin conducted experiments and the precaution of risk was demonstrated highly correlated with self-efficacy ratings ($r = -.657$, $p < .0001$) during six same physical activities in the study of 327 women conducted by (O'Brien Cousins, 1998) She built a composite model of adult physical activity (as shown in figure 1), the model illustrated with 16 variables. After validation of the model, the determinants in the composite model have best explained why senior adults were physically active. Confidence and personal feeling of efficacious for physical activities are the most important determinants of motivating exercise behaviour of the elderly.

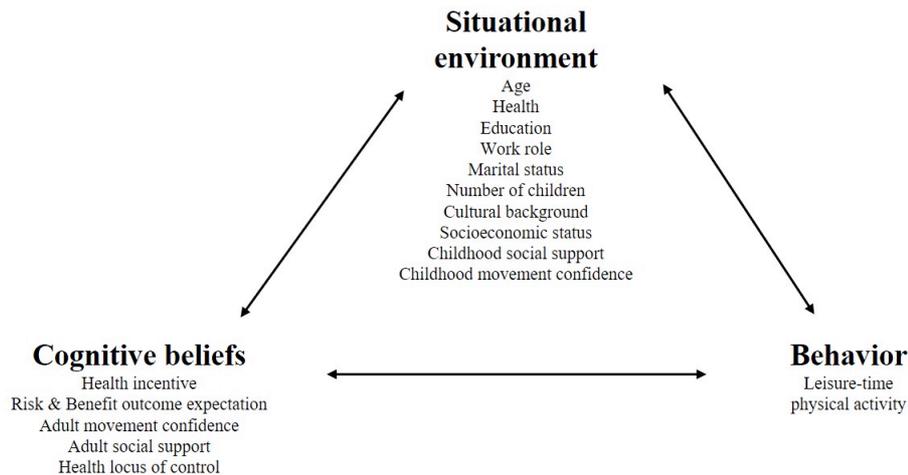


Figure 1. O'Brien Cousin's composite model of adult physical activity.

In other words, it can be understood that people might be motivated to initiate and maintain exercise behaviours if they think they are capable of performing the activity, it strengthens the motivation to improve their perceived efficacy for maintaining adherent behaviour. From the described of self-determination theory (SDT) developed by Deci and Ryan, the exercise motivation originates from physiological or psychological needs that generate a behaviour aiming to achieve a goal. Differently perceived locus of causality scale decided the level of motivation. By the prevalence of SDT on sports and exercise behaviours field, Markland developed Exercise Motivation Inventory determined many motivations of initiating to exercise. (Markland, 1999) These motivations are stress management, revitalization, enjoyment, challenge, social recognition, affiliations, competition, health pressures, ill health, avoidance, positive health, weight management, appearance, strength and nimbleness. (Gefen and Dilmoney, 2007) Based on these theories, for promoting people to wear a sports bra during yoga exercising, the foremost thing is to investigate what kinds of motivations influence them most and how to utilize external motivations internalize. Improving their motivation is helpful for initiating and persisting this behaviour.

Sports bra as a kind of worn equipment may help to fulfil the psychological and physical needs of exercisers. It also has been regarded as major sports equipment plays an important role in improving the performance of exercise directly, prevention of exercise-induced breast injuries and improving their confidence psychologically. (McGhee & Steele, 2010; McGinnis) Despite the existence of a large amount of commercial sports bra, there is still a lack of ergonomic design of sports bra to satisfy the demands of aesthetic, comfort and support (Brown, White, Brasher, & Scurr, 2014; Yu, 2011) What is more, limited researches focused on the study of sports bra design for senior women aged above 55 years old. Women in this aged area have a lot of breast perceptions that accordingly changed their psychological and physical demands on a sports bra. There is an amount of evidence to support the idea that the ageing process has a profound influence on the mechanical properties of their breast. To be specific, as the age increases, the proportion of glandular tissues are decreasing and the proportion of fat tissues are increasing, the skin becomes laxity, less stretched Cooper's ligaments caused an inferior lateral migration of the breast tissues. (Risius) Despite the fact of large differences between senior women breast and younger women breast, current intimate garment market emphasis on the development of bras designed for younger women that do not fulfil the physical and psychological demands

for the older women. Previous literature found that large breast size of women and ill-fitting of a sports bra would exert much more loadings on the thoracic and surrounding musculature resulted in thoracic pain. The breast size and BMI index of the postmenopausal women proved to have a positive relationship with the thoracic pain. This may be due to post-menopause has an effect on the spectrum of anthropometrical changes, which potentially results in altered biomechanics and affect pain states. (Spencer & Briffa, 2013)

Researches in the domain of human breast kinetic and kinematic analysis typically focused on the displacement measurement between the breast and human torso. The motion capture system was the most widely used method to track the makers' movements placed on the breast and the human body during the running or walking. Researches regarding the measurement of the bra and breast during individuals doing activities are limited. One finding on the kinetic measurement of the breast shows that the breast acceleration had been moderated by the supporting level of a sports bra, as well as changing the exercise intensive (yoga, walking versus running, rope skipping). (Greenbaum, 2003) When a woman upright standing statically, there is an anterior torque on the thorax caused by net bare breast forces. (Scurr, White, and Hedger, 2011) In order to test this torque force, Chris developed the buoyant forces provided by water and soybean oil to estimate the non-loaded neutral nipple position. (Chris, 2016) It concluded that gravity plays an important role in effecting the static nipple position, particularly the directions of inferior and posterior. Scurr et al. quantified multi-dimensional breast displacement during walking and running on a treadmill under bra and braless conditions. It is concluded that there is a significant effect of reducing the amplitude of breast displacement under sports bra during treadmill activities, but the motion direction of the breast during walking and running was unaffected. (Scurr, White, & Hedger, 2011; White, Scurr, & Smith, 2009) With regard to the kinematic measurements, McGhee et al. had quantified the motion of breast relative to trunk and foot by infrared emitting diodes on participants' several selected points under the bra condition. (McGhee 2003)

However, the biomechanical analysis of senior women during yoga poses was neglected which it is difficult to investigate the tiny differences among activities, which is crucial to study the physical performances during doing activities. Women who wore the sports bra not only anticipate to alleviate the breast sagging problem but also to mask the sign of ageing. Specific design for senior women has become an essential target for this study. The purpose of this study is to assess the need of senior women on the sports bra based on the health exercise behaviour theories and models and further to provide an instruction of sports bra design for senior women to fulfil their psychological and physical needs.

3 Research methodology

The yoga bra is a kind of intimate which next to human skin, the comfort of handle feel and the comfort feeling from external bra are an instant and direct transfer to the wears' perception (Yu 2011). The handle feeling of fabrics usually tested from the aspects including softness, stiffness, smoothness, itchy, prick, roughness, crispness, tightness etc. (Klatzky and Lederman 2010). Mostly evaluated by subjective methods such as questionnaire because people's perceptions is difficult to be quantified by testing mechanical approaches. Coupled with the motion analysis to evaluate the breast movement with and without sports bra, it is reasonable and systematic to evaluate the key performance of sports bra.

The roadmap of the methodology was shown in figure 2. In order to propose the design criteria of the age-friendly sports bra, the key performance variables should be identified at first. This part can be obtained by the questionnaire survey to get an understanding of the subjective needs from the psychological dimension, coupled with the conduction of the motion capture experiments to collect the biomechanical behaviour of the senior women breast from the physical dimension.

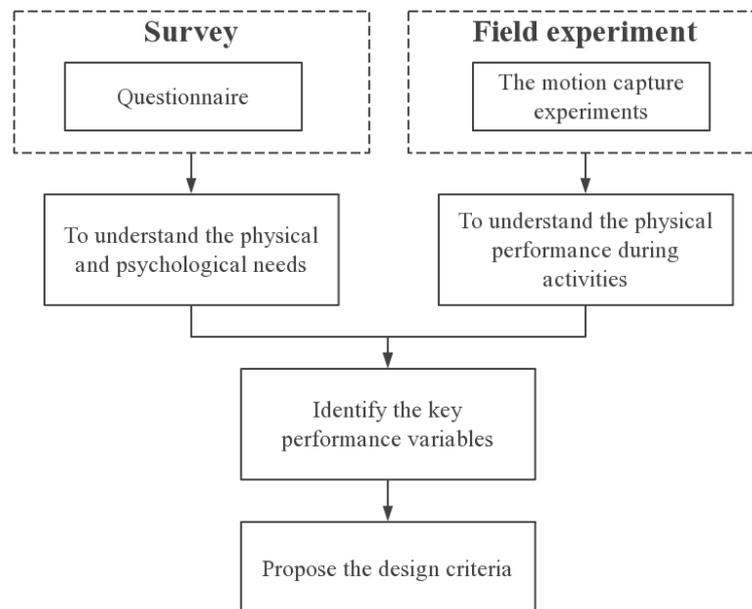


Figure 2. The roadmap of methodology.

Identifying the reasons for senior women to engage in the yoga exercise was thus necessary to improve their motivation in yoga exercise by properly designing the psychological satisfied sports bras. According to the previous literature, senior individuals weighted the estimated benefits against its costs and risks from doing physical activities (Conn, 1998) At the same time senior women are strongly driven by health-related goals aiming to keep them healthy. (Giles, 2004) As a result, it is necessary to study the perception of senior women on yoga exercise benefits. Thus, the reason for participating in yoga exercise was included in the questionnaire items. Following was to investigate if the sports bra motivate the senior women engagement into the yoga exercises, what kinds of sports bra components influence their attitude and needs on the sports bra. Therefore, this item was involved in the questionnaire. Different exercise history of yoga was assumed to have different influences on senior women’s preferences and perceptions on the sports bra, so the yoga exercise history was included, and the considered factors of wearing a sports bra during doing exercise was also included into the questionnaire and designed in multiple-choice questions, which can be also used to propose the sports bra design criteria specialized for the senior women.

Besides the questionnaire, it is equally essential to analyze the biomechanical behaviour of senior women breasts, so the field experiment was conducted to collect the breast deformation during the participants doing yoga poses. In this study, motion capture method was adopted to collect three-dimensional trajectories of selected points on the breast. From

the data captured on the senior women during 2 selected yoga poses, the skin extension and approximate whole breast deformation can be analyzed. Combined the questionnaire results and the breast motion characteristics, the needs, features of senior women on the sports bra were understood. Accordingly, the age-friendly sports bra design criteria were proposed.

3.1 Questionnaire data collection

Regarding the current study focused on analyzing the influence of age and consequent exercise behavioural reaction, purposive sampling was introduced to improve the generalizability of the results as an accurate representation of the population to a large extent. Therefore, we began to collect survey responses from online sampling. In total, 229 unique responses. 170 participants were equal below 39 while 59 participants were equal or above 40.

The Self-Determination Theory (SDT) has a wide range of applications in a different field of exercise psychology research. (Duda, 2006) By using SDT aimed to examine the relationship between motivation and exercise behaviour. The individuals with different level of motivations (intrinsic motivation, extrinsic motivation, and motivation) (Miller, Deci, & Ryan, 1988) results in different possibilities to persist or dropout behaviour. Intrinsic motivation is expected, people have intrinsic motivation can perform behaviour autonomous and feel enjoyment which is expected to have a higher level of participation. Extrinsic motivation refers to the situation in which people perform one behaviour for competition, environmental factors, the rewards. For example, the senior women participant in the yoga exercise because they wanted to present their ability to others or because they followed their peers. Amotivation is the situation in which a lack of intentionality.

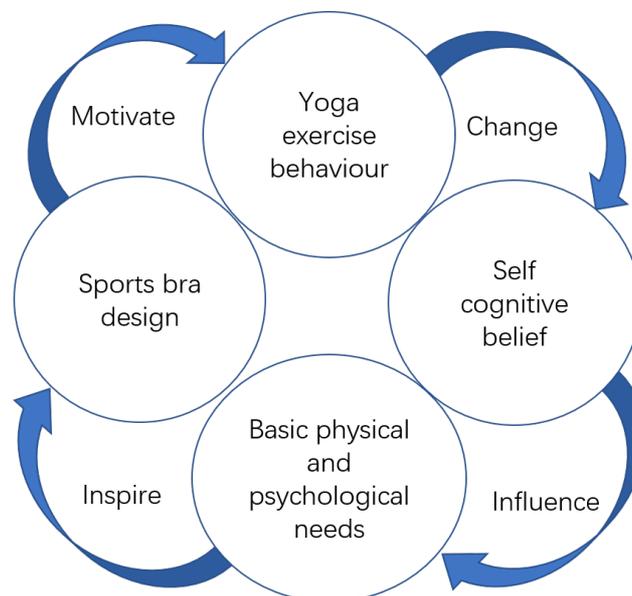


Figure 3. Conceptual model of sports bra and yoga exercise for senior women.

Figure 3 shows the conceptual model of the sports bra and yoga exercise. It is assumed that self-cognitive belief influences their basic physical and psychological needs. Their needs accordingly inspire to design the sports bra more age-friendly and the optimized age-friendly sports bra works as an incentive to motivate the senior women to be involved and persistent in yoga exercise.

The reason for participation in yoga exercise was included in the questionnaire. The aim was to identify the motivation differences between senior women. Following was to explore the

motivational determinants of sports bra on a different period of yoga exercise history. The physical and psychological needs of senior women on the sports bra were included. The self-cognitive belief is predicted to occur exercises behaviour for senior women. If they do yoga exercise because the health-related factors (incentive to act, benefits), or they are enjoyable to do yoga exercise (self-efficacy) Questions regarding the purposes of wearing sports bra included items “feel confident”, “show out the body”, “avoid accidental exposure”, “provide stable support” are related to the self-efficacy which are the indicators for better activity performed under the help of sports bra. So maybe can motivate by extrinsic motivation. Besides, some items namely “peers have bought”, “famous brands of sports bra”, “recommendation of friends”, “recommendation of social media” are assumed belong to one of the four cognitive constructs - social/environmental influences. According to the previous studies, (Zhou, Yu, & Ng, 2013), effective sports bras shared common features or functions such as comfort, support and aesthetic. As a result, “wear comfortable and not tight”, “breathable perspiration”, “provide stable support”, “good looking” are included in the questionnaire. Considering the special for declining functions of the senior women body, for example, senior women cannot lift hand over the shoulder, reduced muscle strength. The performance of sports bra regarding the “easy to wear, easy to take off” is involved.

3.2 Motion capture data collection

Motion capture system is a set of equipment which is used to measure motions and record the motion of objects in three-dimensional space as shown in figure 4. It has been widely used to measure kinematics and kinetics data of participants. In the past, the subjects were asked to evaluate the systems and respond to questionnaires. While nowadays some more advanced and rigorous approach is developed to obtain human’s kinematic evaluation and analysis. In the beginning, the infrared reflective markers are attached to the specific positions of the targeted objects. Followed by tracking and recording the three-dimensional trajectories of those markers by using 12 high-resolution digital cameras. After the reflected signals were captured, the motion data will be transferred to the computer system for further biomechanical analysis. Usually, the raw data directly recorded by the motion capture system has some missing points. The acquired data was not qualified for analysis. Data cleaning and filtering are imperative for the accuracy of further data analysis, which can be finished on the motion capture system.

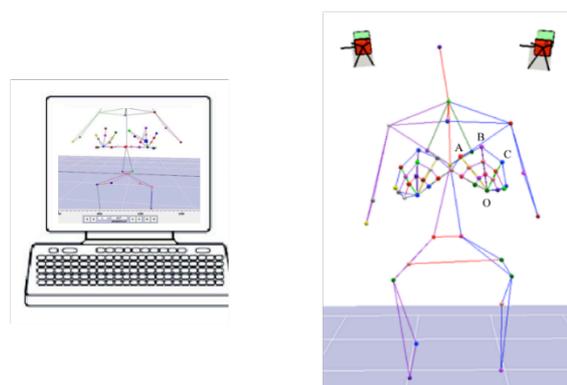


Figure 4. The retro-reflective markers captured by the motion capture system preview on screen.

In this study, the motion capture system (Eagle, Motion Analysis Corporation, US) is adopted because of its advanced sensitive and reliable data capture ability. This type of system directly measures markers and followed by analysis algorithms to get attitude. The arrangement of those markers should be careful. Markers on selected locations on the human body should not change relative distances. Each marker should be posited as far

away from each other for reducing computational errors in the attitude and increasing sensitivity. The placement of the infrared reflective markers is shown in figure 4, herein, 31 markers are selected in total (with a diameter of 9.5 mm) for the breast. The markers are attached on the nude breast. It is well-known that the female breast covers from the anterior axillary in the horizontal direction to the costal cartilage and sits from the second rib in the vertical direction to sixth/seventh rib. The outer upper quadrant of the breast tissue extends towards the axilla. Before starts the record, the motion capture system should be calibrated. Then the participant was asked to stand at the centre of a camera focused, following she will do the arm abduction position from 30° into 90° in the horizontal direction on both sides. The real-time 3D coordinates in x, y, z directions of marked points A, B and C were measured and recorded during the participant doing abduction.

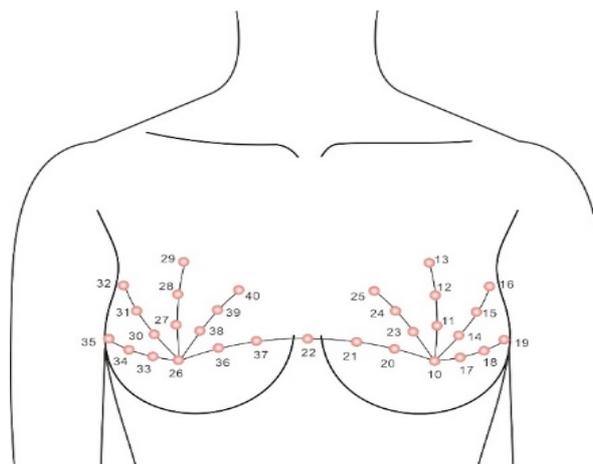


Figure 5. Placement of motion capture markers on the breast.

The researchers received the approval of conducting the motion capture experiments from the School of Design of The Hong Kong Polytechnic University. Prior to the experiments, the participants have informed the content and purpose of this research. All of the participants were signed the informed consent form. Their personal information remained confidential and all the experimental data will not be disclosed. Participants are selected the female at the age from 60 or above without any breast surgery history which was selected strictly based on selected criteria.

One participant volunteered for this study, whose age is 65 and meets the subject recruitment criteria that is no breast surgery history and muscle of body functional problems, The motion including 2 yoga poses from bare skin, motion capture was conducted using EVaRT5 to collect the marker data and data clean-up after measurement. The 2 yoga poses are Warrior I, Warrior II as shown in figure 5. Those two kinds of yoga poses will lift arms in different directions, they are upward and lateral, respectively. The reason for choosing these 2 yoga poses is to investigate the differences in the skin extension of the senior women breast when the breast was stretched in different directions.

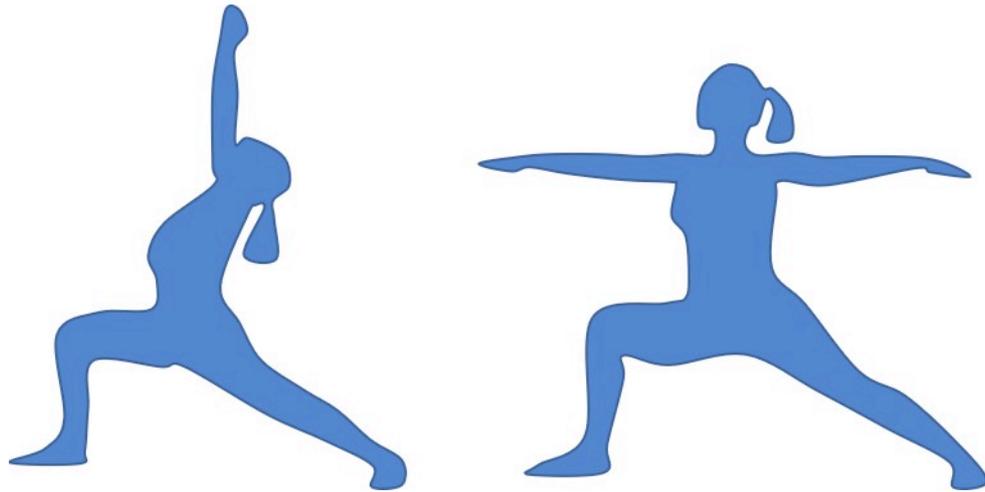


Figure 6. The selected 2 yoga poses for the motion capture experiments, Warrior I (left), Warrior II (right).

4 Results and discussion

4.1 Analysis and results of the questionnaire

The reasons for participating in Yoga exercise was shown in figure 6. It can be found that “lose weight and stress reduction” and “relax mind” are the two major reasons why senior adults take part in the yoga exercises. Followed closed by physical fitness exercise and improvement of temperament or gesture. The result expresses a combination of mental and physical reasons from the perspective both the self-efficacy and the perceived benefits. Other emerging themes like “feels good” (15%), “enjoyment” (4%), and those “who feel it has become a part of their lifestyle” (4%) indicates that participants to do yoga practice is somewhat due to the precaution of benefits outweighed its costs/risks which persistent them to adhere the exercise practice, they think they can perform well although exercise is a complex, time-consuming. The relax and stress relief of the yoga exercise outcome promote their self-confidence, encourage them as motivation. It goes obvious that participants who had longer yoga practice history reported being motivated more which can also be explained by integrated regulation and intrinsic motivation. In other words, those who have practised yoga report more autonomous forms of motivation.

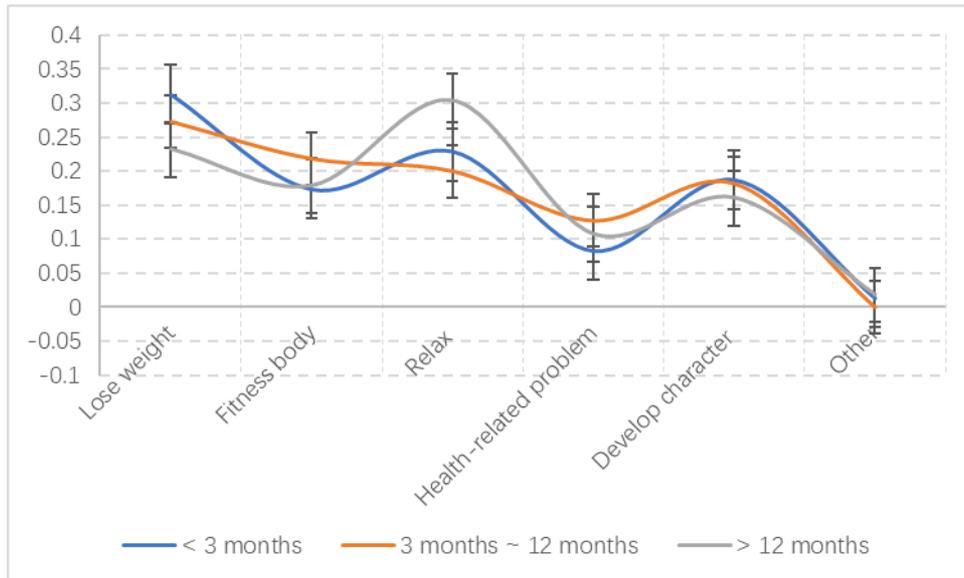


Figure 7. The reasons for participating in Yoga exercise.

As shown in figure 8, “wear comfortable”, “breathable perspiration”, and “easy to wear and take off” are three main demands for participants’ selection no matter how long of the participant’s yoga practice engagement time. So, the senior women may pay more attention to the comfort and support of sports bra. It also should be noticed that “the demand of sensor of ritual” in three months’ yoga practice history has a larger proportion than who has half a year and more yoga exercise history. This is a result of that “the sense of ritual” motivates yoga beginners to start yoga exercise. SDT theory indicated that behaviours are fully integrated with the self-concept, values, goals. (Sanli, Patterson, Bray, & Lee, 2013) “The sense of ritual” satisfies the psychological needs to motivate exercise behaviour which is totally incorporated into the behavioural repertoire. “Feel confident” it seems more important for participants with more than one-year yoga practice history. These results also indicate that integrated regulation may play a role in individuals’ abilities to reach the transformed stage of change for practising yoga. In other words, sports bra may help participants internalize to do yoga practice over time.

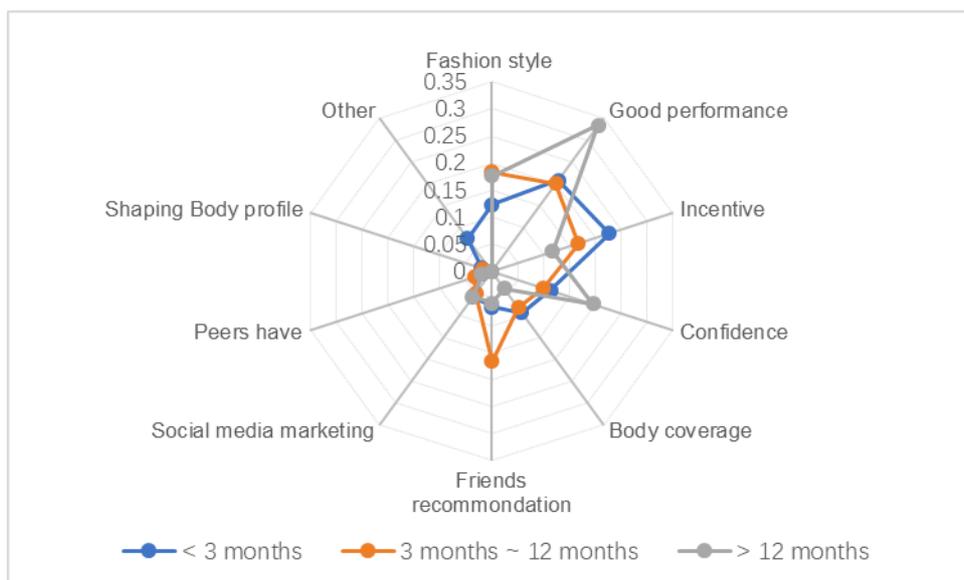


Figure 8. The considered factors of wearing a sports bra for senior women with different yoga exercise history.

4.2 Biomechanical analysis of motion capture

To describe the movement of the senior women breast, the skin extension of the breast and how the breast deforms during the two selected yoga poses should be analyzed. The linear displacement of the selected points on the breast surface was calculated. All kinematic displacements of the points were assumed as a two-dimensional basis in one plane. The linear displacements of the selected points are calculated by the equation:

$$\lambda = \left(\frac{\Delta L - \Delta L_0}{\Delta L_0} \right) \times 100\%$$

Herein, the ΔL presents the original displacement while the ΔL_0 presents the deformed displacement, the λ presents the strain.

Because the differences in the strain λ are too small to obviously observe. The strain λ takes the form of the logarithm. The skin extensions from bare skin are calculated by using the software OriginPro (OriginLab Corporation, USA). The results of the skin extension under the different status of 2 poses are shown below. The down position in figure 9 means the arms at the lowest position 45° angle of the gradient with the trunk on two sides. The up-position means the arms lift over the head.

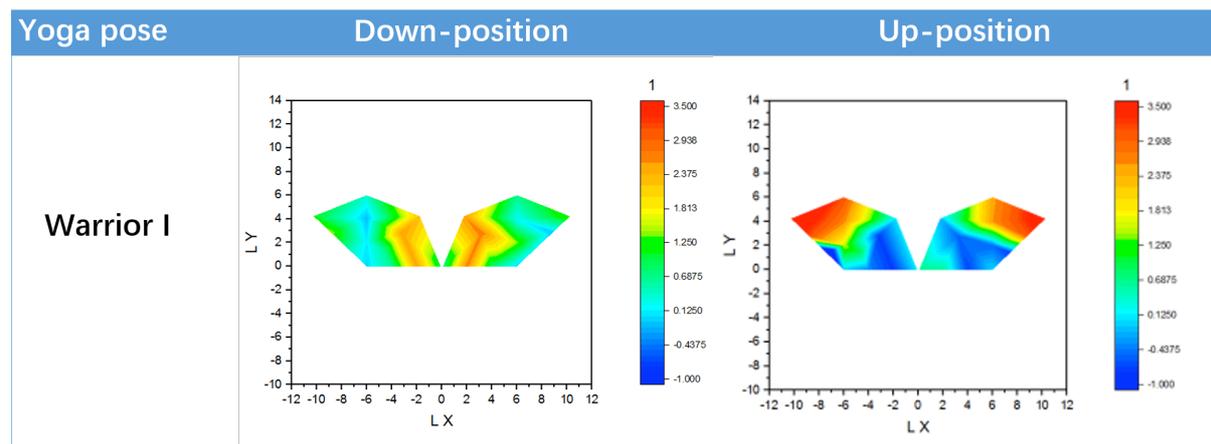


Figure 9. The visualization of motion results of yoga pose: Warrior I.

While the medium-position is the start of the Warrior II. The arms put together at the medium height in the centre director and the T-position is the end pose of the Warrior II as shown in Figure 10. The magnitude of the displacement as shown in the right hand of the graph. The value varies from the lowest to highest is a small value to big. In the down position of Warrior I, the displacement of each part on the breast seems closed. Only slightly orange colour in the centre of two breasts which mean there is stretched, while the green colour can be seen in the upper outer part on the breast means that this part is contracted.

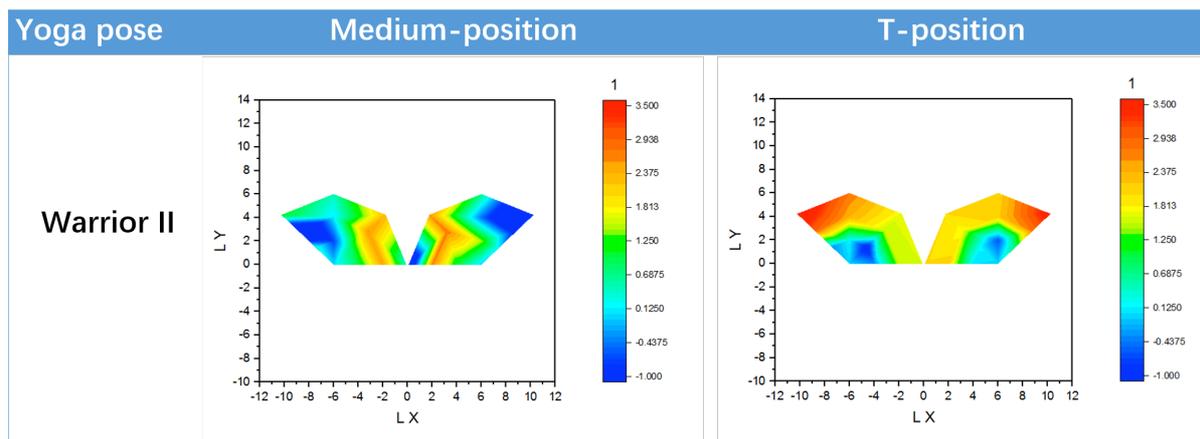


Figure 10. The visualization of motion results of yoga pose: Warrior II.

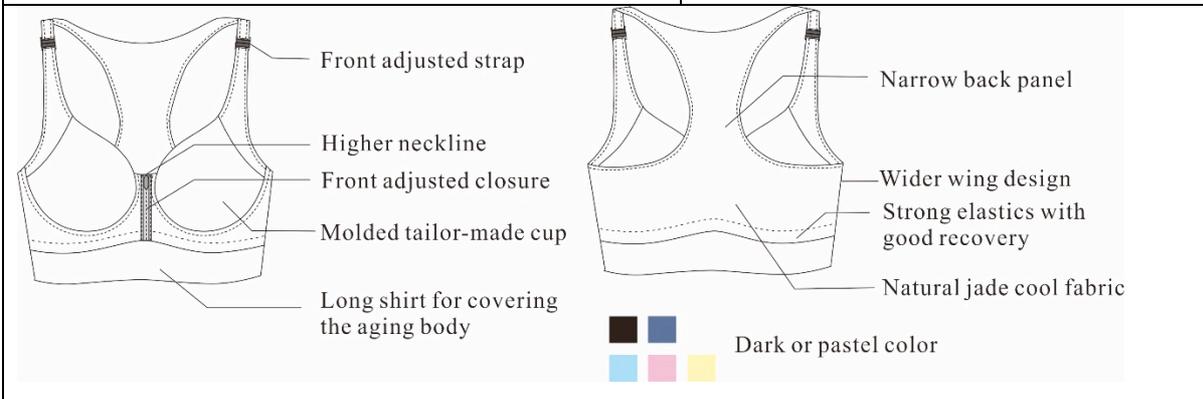
Figure 10 shows the motion results of Warrior II the arms rotated from down-position to up-position, the area of red colour in the upper outer part is the most extended part at that moment, on the other hand, the blue colour representing the tightened part in the centre of two breasts. It shows the upper outer part of the breast has the largest positive value which indicates this part skin is stretched largest, while the centre of two breasts has the negative value means that the place is contracted. It is demonstrated that the displacement is increasing as the arm uplift, especially when the hands are raised up, the extra support is needed on the upper cup for senior women when doing exercise. When it comes to talking about the skin extension during Warrior II, the deformation of the linear displacement is similar to that of down-position. However, the level of the linear displacement change of medium-position is larger than that of down-position. This may be due to the push force of arm on the breast when arms put together. When medium-position pose changes to T-position, all boundary part both of the inner and outer part are stretched. Conversely, boundary part to left nipple and then the right nipple is stretched in a lower level compared with the boundary part, it means nearly the nipple point maintaining the lower level movement during the change of the arm position. At the t-position, nearly the whole breasts are stretched at a large extent. This also indicates that the senior women breast has a large deformation during doing yoga. The large deformation may further influence the stability of the breast, and repetitive deformed breast may result in lack of the support structural system inside the breast and serious breast sagging. In order to avoid this situation, the sports bra designed for senior women should pay more attention on the support.

4.3 Propose of the sports bra design criteria

Some researchers concluded the features of the most effective sports bra that are short vest style, high neckline, slings, cross back, bound necklines, no center gore, no wire, no cradle, no pad and a non-adjustable wide strap (Zhou jie, 2013, Zhangshichen, 2018). The breast displacement can be reduced by the improvement of the gore height, shoulder strap width, neckline height and side seam depth. The design criteria were established based on the needs of older women in over 10 design features of construction based on the previous questionnaire results and motion capture results. To address every need and aims to provide effective support, comfort and stability, the specific design features were made based on the result of content analysis, in terms of fabric, elastics, and over 10 features of construction. For each need, design features were concluded from bra samples by

frequency analysis in wear trial comments. Therefore, the design criteria can be summarized based on the good design features and bad design features under each theme.

Table 1 Design criteria of aged-friendly sports bras

Needs	Design criteria
Fabric	Breathable Thermal comfort Natural jade cool fabric Odor resistance polyester knitted fabric Breathable and thin materials
Elastic strap	No spreading Easy to adjust Easy to wear Easy to move Adjustable straps and closure Front adjusted strap wide enough Strong elastics with good recovery
Neckline	No exposure Higher neckline
Back	Large movement space Hidden back fat Not cross-back and pull-over bra Back design: Narrow panel
Armhole	Large movement space Concave panel
Cup	Round breast shape No sagging Molded tailor-made cup for older women
Side panel	Lift up the breast Special cutting to lift up and firm the breast
Aesthetic	Fashionable Look younger Dark color or pastel color Long shirt for covering the aging body Color matching
Closure	Easy to wear Easy to move Front adjusted closure
Wing	Better coverage Wider wing design
 <p>The diagram illustrates the design features of the sports bra. The front view (left) shows a front adjusted strap, higher neckline, front adjusted closure, molded tailor-made cup, and a long shirt for covering the aging body. The back view (right) shows a narrow back panel, wider wing design, strong elastics with good recovery, and natural jade cool fabric. A color legend indicates dark or pastel colors.</p>	

5 Conclusion

The needs of the older women on the sports bra are explored by conducting the questionnaire survey, combined with results of the motion capture results on the nude breast of older female participant, the design criteria of the sports bra for the older female users is proposed. Design specification of age-friendly bras in biomechanical fitting terms for various bra components and construction will be helpful for the development of sports bra. The development of age-friendly sports bra can not only satisfy the physical needs but also can fulfill participants' psychological needs, then motivate them to wear sports bra and to initiate and maintain the yoga practice because the extrinsic motivations are more effective than intrinsic motivation at the beginning period. Those who have practiced yoga for longer periods of time would be more autonomous forms to do yoga exercises.

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