Development of functional racing singlet for professional rowers

Abstract

Rowing is an activity which requires participants to use their whole bodies in a sitting position. Rowers must propel a boat using their arms, legs, back, and shoulders, executing all movements within the vessel. An appropriate racing singlet designed for their unique movements is essential for professional athletes' training and competition. To meet this need, a university research team, a garment manufacturer, and the Hong Kong rowing team collaborated to develop a new singlet for their participation in the 2014 Asian Games. A design process framework developed by LaBat and Sokolowski (1999) was adopted to facilitate the design process. The research team helped the rowing team to improve the garment fit, seaming and stitching, garment construction, and fabric options. To meet the high expectations of the rowing team, a tailor-made approach that involves using a 3D body scanner was adopted to achieve the individual fit preferences of each athlete.

Keywords: Functional garment, design, rowing, sport

1. Introduction

The 2014 Asian Games were held in Incheon, South Korea from 19 September to 4 October. In the rowing competition, the Hong Kong team won their first-ever gold medal (men's lightweight single sculls), as well as four silver medals (men's lightweight double sculls, men's lightweight quadruple sculls, women's single sculls, and women's lightweight single sculls). These were the best competition results in the history of the Hong Kong rowing team.

Seven months before the 2014 Asian Games, the university research team initiated a project to develop a new functional racing singlet for the Hong Kong rowing team. To ensure the quality of the product, a local garment manufacturer was appointed to join this project for material sourcing, prototyping, and final production. The Hong Kong rowing team, under the Hong Kong Sports Institute, was involved in the entire development process. During this time, the research team and local manufacturer visited the rowers to learn their expectations for the new singlet design and explore the shortcomings of the current singlet.

A racing singlet is designed to satisfy a unique mix of user needs. This garment should be comfortable, aerodynamic, highly breathable, lightweight, sun protective, and appropriate for the daily practice of rowing team members. Previous studies have summarised that except for sport equipment, the body positions and garments of athletes are the two most crucial factors affecting athletic performance (Chowdhury et al., 2009; Moria et al., 2010; Kyle et al., 2004).

The purpose of this project was to develop a new singlet for the Hong Kong rowing team for assisting them in their upcoming competition. As suggested by Kim and LaBat (2010), a design process framework is a vital guideline for design teams planning projects for clients. In this study, LaBat and Sokolowski's (1999) design framework was adopted, and it proved useful for providing relevant information to different parties and communicating design decisions.

2. Literature review

2.1 Rowing: Body movement and clothes

Race rowing has been an official event in the Olympic Games since 1896 and was first incorporated into the Asian Games in 1982 (International Olympic Committee,

2015). Rowing is a sport in which athletes sit facing backwards and push oars against the water to generate reaction forces that propel their boat forwards (Olympic Council of Asia, n.d.).

Rowing consists of two forms: sweeping and sculling. Sculling uses two oars per rower, whereas in sweeping the rower holds one oar only. In the Olympics and the Asian Games, sculling is the official form of rowing competition. Sculling strokes can be divided into six phases: (1) preparation, (2) entry and first half of the drive, (3) finish of the drive, (4) finish and release, (5) first half of the recovery, and (6) second half of the recovery (Nilsen, 2009). Each phase requires different techniques of concerted motion. Apart from controlling the oars with their arms and upper body, the rower also must use leg force to push the sliding seat to increase speed. In each cycle of sculling strokes, the rower must extend the shoulders, chest, back, abdomen, buttocks, thighs, and legs. According to international standards, races are held on water over 2000 m, and each competition typically lasts 6 to 8 minutes (Smith & Hopkins, 2012; Soper & Hume, 2004).

The clothing worn by rowers must comply with the rules and regulations of the OCA (Olympic Council of Asia) and FISA (Fédération Internationale des Sociétés d'Aviron or International Rowing Federation). According to the rule book of FISA (2014), the equipment and clothing for racing should meet the following requirements: be commercially available to all competitors; not substantially add to the cost of the sport; not provide an advantage to any competitors over others or change the nature of the sport; be safe and environmentally sound; and be a positive development for the sport of rowing and maintain its principles of fairness and equality. The racing shirts in most international competitions are of the ‘singlet’ or ‘sleeveless shirt’ style.

2.2 Design model

Design is a tool for solving various problems. Design processes are used for specific purposes in many occupations such as architecture, environmental design, engineering design, industrial product design, and textile product design (LaBat & Sokolowski, 1999). Although there are numerous variations among design processes, their common goal is to help designers solve problems through specific structures and stages of a process model. Design processes are useful for enhancing creativity, providing useful information, preventing product failure, and avoiding unnecessary retesting (Kim & LaBat, 2010). The complex tasks of identifying and translating needs into garment attributes are accomplished through the design process (Bye & Hakala, 2005). The rowing team singlet design project described herein involved the collaboration of a university research team, a manufacturer, and the end users (the rowing team). A suitable design process model was therefore vital for providing each party with a structural approach. The framework proposed by LaBat and Sokolowski (1999) was adopted to promote collaboration based on the strengths of each party. The model was tested during the cooperative redesign of an athletic ankle brace by the manufacturer and university. For this model, the researchers concluded that three major phases should be followed: (1) problem definition and research, (2) creative exploration, and (3) implementation.

In the first phase, the coach and the rowers defined the preliminary problem. The university research team investigated user needs and the features of the current racing singlet such as fit, material, function, and garment construction. This phase provided useful information for each party to redefine the problems of the design process and set the criteria by which they would evaluate current and newly designed products.

The research team ideated and refined design ideas during the second phase. After defining the key problems of the current singlet, the research team worked with the rowers, coach, and garment manufacturer to suggest possible solutions. At this stage, brainstorming among the three parties was crucial. Each party could share different ideas based on their areas of expertise, experience, and knowledge. The ideas could then be refined through evaluations in the prototype development and wear trials.

After fine-tuning the details, a final design was approved in the implementation phase. Bulk production was executed and the final singlets were delivered to the rowing team before their participation in the 2014 Asian Games.

3. Design process part 1: Problem definition and research

Before designing the new singlet, the research and rowing teams discussed the project tasks and schedule. The discussion was conducted in a focus group format involving the rowing coach and 15 rowers (nine male and six female). All representatives from the rowing team were local Chinese. The aim of the focus group was to determine the functional, aesthetic, and quality requirements for the new singlet design. Scholars suggested that the ideal size of a focus group interview for most noncommercial topics is five to eight participants (Krueger & Casey, 2009). However, because the purpose of this project was to design a satisfactory racing singlet for every rower, all rowers were invited to attend the group interview and share their experiences. This method was expected to address all problematic features of the current rowing singlet.

The current rowing singlets (Figure 1) were purchased from an online shop of an overseas company which specially produces sport clothing, rowing singlets, and rowing equipment. Each time they placed an order, the rowing team members

specifically requested that the company embroider a Hong Kong flag on the front of each singlet. The details of the current singlet are summarised in Table 1. After the focus group interview, the rowers addressed the following key problems that they found with the current singlet.

3.1 Fit problem

For normal garments, 'fit' is determined with the wearer standing still. However, the meaning of 'fit' in athletic clothing is associated with the specific movements generated by the wearer. This type of functional clothing must fit the body so that the wearer can move, sit, and perform work duties or athletic activities (Boorady, 2011). In this study, both the male and female rowing team members were satisfied with the length of the current singlet but not the fit. Their judgement of the fit was based on the garment performance while each rower executed sculling movements. The sizes available for the current singlet (i.e., XS to XXL) were generally sufficient; however, they could not satisfy individual fit preferences. Some of the rowers preferred a tighter fit, whereas some did not. For example, one male rower commented that size M fit the lower body but the upper part was too loose, whereas another rower stated that size L fit the upper body but the waist and bottom were too loose. Extra fabric formed if the bottom half of the singlet was too large. When a rower is sitting in the boat, extra fabric draped around the abdomen can hinder sculling movements by trapping the handles of the oars. It is also vital that a tight-fitting singlet allow for the extension of muscles in sculling.

3.2 Scratchiness problem

The rowers informed that the singlets caused discomfort while they were sculling. The research team evaluation revealed that scratchiness problem was caused by the

seam location, style of stitching, and the overall construction of the singlet instead of the fabric itself. This problem was mainly reported by the male rowers.

The seam of the current singlet was mainly constructed with a 514 four-thread overlock stitch (ASTM D-6193), including the joining of black, red, and white panels on the front and back. The hem and collar edges were finished with a 406 cover stitch (ASTM D-6193). The singlet also had two side seams.

During formal training and competition, most male rowers forgo wearing underwear, to reduce restriction and maximise the effect of pushing against the sliding seat in the boat. The crotch seam of the current singlet cuts across the centre front and back of the lower half, causing discomfort to the penis and scrotum (Figure 2). This problem was exacerbated when sculling actions were performed. The research team initially deemed the construction of the crotch to be the main factor in this problem; however, the seaming and stitching were also possible causes.

Furthermore, all the male rowers mentioned that the overlock seams on the front, back, and sides, which were used to join different-coloured panels, scratched their skin when they performed sculling movements. They also commented that the Hong Kong flag sewn on the chest created friction. The flag was approximately 6 cm in diameter, and was embroidered with stitching that was visible on the wrong side of the fabric (Figure 3). Because the female rowers wore sport bras and underwear during training and competitions, the crotch, seam, and Hong Kong flag embroidery did not create noticeable friction against the surface of the skin.

Both the male and female rowers mentioned that their underarms were scratched by the armholes of the current singlet while they performed sculling movements. The research team and manufacturer observed that this friction was

caused by the tightness of the armholes rather than the seaming or stitching on the edges. Because sculling involves stretching the chest, back, and arms, the friction between the armhole edges and the skin was considerable.

3.3 Fabrication

The rowers were satisfied with the weight, texture, and breathability of the fabric used in the current singlet. Before the fabric was sourced, the coach and rowers reminded the research team that the weight of the singlet was crucial. For each rowing event, each rower is weighed. According to the FISA rule book (2014), the maximum weight of a rower wearing a racing uniform in lightweight rowing events is 72.5 kg for men and 59 kg for women. To ensure that the fabric did not add excessive weight, lightweight fabric options were chosen. The coach and rowers were amenable to any new, beneficial functions of potential singlet fabrics.

4. Design process part 2: Creative exploration

The researchers focused on the feasibility of various possible solutions at this stage. After considering the lead time, cost, and manpower involved in the project, prototypes and wear trials were arranged for the rowers.

4.1 Tailor-made approach to eliminate fit problems

The research team realised that mass-produced singlets could not satisfy the individual fit requirements of each rower because of the limited size range. Chowdhury et al. (2012) stated that garment construction affects the effectiveness of specific active wear. A proper fit plays an essential role in the development of high-performance sport clothing. This garment should allow the athlete to move freely, but at the same time it would not create extra fabric drape to hinder the body movement.

However, it is difficult to design and develop commercial sport clothing to fit every unique body. Chowdhury et al. (2011) studied the fit of ski jumping suits and their correlation with athletic performance. They concluded that athletic clothing should be made according to the body measurements of the athlete in order to improve performance. Hence, the production of tailor-made singlets was proposed for the rowing team in this study.

Although the production time and cost of tailor-made singlets are comparatively high because of the series of trials necessary to achieve a correct fit, the fit can fulfil individual requirements based on experiences in daily training and frequent competition. All parties in this collaborative project believed that a correctly designed singlet was one of the key means for rowers to improve their performance in competition. The traditional tailor-made method requires a longer production time because of the need for individual body measurements. However, 3D body scanners could potentially overcome this disadvantage and eliminate the errors of manual measurements. At this stage, a 3D-laser body scanning system equipped with Scan WorX firmware was used to collect anthropometric data from the rowers. After scanning, the data were sent to the manufacturer for constructing the first prototype. In this preliminary singlet, no ease or measurement allowance was given for body circumference, to ensure that the new singlet was a perfect fit for the individual. However, the length of the current singlet was used as a reference to develop the new singlet, unless individual rowers had complaints about the garment length. This was based on an observation of the research team, that reasonable ease should be allowed for singlet length because it is necessary for performing the sculling movement, which requires the rower to bend and stretch the body.

4.2 Improvement of singlet comfort by changing fabric seam, stitch types, and garment construction

To eliminate the problem of scratchiness, the fabric seams, stitch types, and garment construction were altered. The Hong Kong flag on the chest was altered to a nonembroidered design. All changes were decided on by the university research team and garment manufacturer according to their experience and the input from the rowing team. The changes were explained to the team before the production of the first prototype.

To reduce friction caused by the seams, the manufacturer suggested that the new singlet use only flatlock seams with 607 cover stitch (ASTM D-6193) to provide smooth, flat, and bulk-free joints. The advantage of the flatlock seam was its ability to reduce the discomfort caused by friction between the seam and the skin.

The Hong Kong flag on the chest was replaced with a 3D polyurethane badge. The badge was attached to the fabric surface through heat transfer so that there would be no stitching on the wrong side of the fabric (Figure 4). The two badges differed in appearance and texture. The advantage of the heat transfer badge was that the lack of stitching on the wrong side of the fabric would reduce friction against the skin.

4.3 Construction of singlet armholes, side seams, and crotch

The research team observed that the forearms, arms, shoulders, chest, and across back of the rower were extended during a complete cycle of sculling movement. After consulting the garment manufacturer, the researchers determined that the armhole of the new singlet could be cut wider and deeper. The back of the singlet was trimmed more towards the centre. This not only avoided the problem of scratchiness caused by

tight armholes but also let the rower move with less restriction. However, this change was more obvious in the male singlet. The armholes of the female singlet were trimmed moderately to avoid the possible problem of 'flee'. Figure 5 shows back views of the modified armholes of the new male and female singlets. In addition, the side seams on the current singlet were removed to eliminate any possible friction against the skin.

The crotch was cut according to the body shape of the male and female rowers. The centre front seam and centre back seam were removed from each singlet. A gusset was added to the female singlets to increase flexibility; thus, only one centre back seam was constructed as a joint in the lower half of the singlet. For the male rowers, a rectangular panel was constructed to eliminate the bulkiness of the seams. Two seams were constructed along the front side panel in accordance with the body shape of the rower. These two seams were essential in forming a tube-like bottom half and ensuring that there was no seam on the back. All seams at the crotch were constructed with flatlock seam 607 cover stitch (ASTM D-6193). Figures 6 and 7 illustrate the different constructions of the crotch areas in the new singlets for male and female rowers.

4.4 Fabric options and proposed functions

The research team and manufacturer searched for alternative fabrics from the available market during prototype production. During the fabric sourcing stage, the research team proposed adding UV-blocking functionality to the new singlet to protect the body in training and competitions on sunny days. The coach and rowers commented that this function was justified, especially in the summer.

Before deciding on the fabric for the first prototype, a series of tests was conducted for fabric appearance, breathability, colourfastness, and other properties. Table 2 presents some of the testing standards and methods of this project. The cost, weight, and performance under a series of lab tests were key considerations in producing this functional athletic singlet. The final selection for the prototype was a blend of 92% polyester with 8% spandex and a weight of 200 g/m^2, constructed in fine gauge interlock fabric. The elastomeric behaviour of spandex has made it a popular choice for underwear, outerwear, and active wear (Singha, 2012). Because the male rowers did not wear underwear during rowing, a thicker fabric was used (92% polyester with 8% spandex in the weight of 230 g/m^2) to avoid transparency in the lower half of the singlet.

4.5 Prototype development

All possible modifications were organised and reported to the rowing team, followed by development of the prototype for a wear trial. As suggested by the coach, the wear trial lasted 3 weeks so that the rowers could wear the new singlets during training and regional competitions and provide feedback afterwards.

4.5.1 First wear trial

Because production time was limited, not all singlets were pressed with the Hong Kong flag heat-transfer badge. The first prototype was expected to be worn by the rowers for 1 month of training, during which the singlets were washed and tumble dried normally. After 1 month of training, the research team and the manufacturer visited the rowing centre again to meet with the coach and collect feedback from the rowers.

Most of the comments related to garment fit. At this stage, the singlet was tailor-made and there was no extra room left for body circumference. However, all the rowers requested adjustments to the garment fit after the first wear trial. The research team observed two types of fit problems. Regarding the first problem, the rower felt comfortable but needed minor adjustments. This was true of most of the rowers, all of whom preferred their singlets to be tighter. Therefore, the technician adjusted the fit manually (Figure 8); thus, feedback was immediate. The second problem was more complicated, because different rowers had different expectations for garment fit of individual singlet. For example, one rower preferred a tighter top and looser bottom. This fit preference could not be measured during the 3D body scanning. To meet the individual needs of the rowers, the research team requested that the rowers try on the singlets of other teammates to feel the difference in fit. For example, rower X could wear a smaller singlet to feel the fit of the upper part, and then switch to a larger singlet to feel the fit of the lower part. They could then compare different-sized singlets to make final decisions according to their fit preferences.

The male rowers indicated that the new cutting, seaming, and stitching used in the crotch reduced the itching problem of the previous singlet. They also commented that the heat transfer badge of the Hong Kong flag largely eliminated the scratchiness problem. Furthermore, all the rowers mentioned that the larger armholes allowed them to move more freely than did the existing singlet. The feeling of tightness and itchiness caused by the current singlet was eliminated.

The rowers also gave unanimously positive comments on the fabric used in the prototype. They considered its weight to be appropriate, and laundering and tumble drying did not cause any problems with either the fabric or the new Hong Kong flag badge.

After receiving feedback, the research team and manufacturer photographed the rowers wearing the prototype singlets. The photos and verbal comments of each rower were organised in individual computer files. All this information was used to make adjustments in the second prototype.

4.5.2 Second prototype

The second batch of prototypes was delivered to the rowing centre 6 weeks after the completion of the first wear trial. The rowing team planned to wear the second prototype during 2 months of training camp. The locations of the training camps included Qingdao, Lucerne and Tilburg. Before their departure, all the rowers wore the new singlet and operated a rowing machine for 15 minutes to evaluate the fit of the second prototype. This allowed the manufacturer to alter the singlet immediately if necessary. Most of the rowers were satisfied with the fit of the second prototype. Only three male rowers requested further tightening of the singlet because enhanced training after the first trial had reduced their body weight by approximately 5–6 lb. The manufacturer then amended the singlets and returned them before the rowing team departed for training camp. At this stage, all singlets were pressed with the Hong Kong flag heat-transfer badge.

5. Design process part 3: Implementation

After the second wear trial, all revisions of the singlet were completed and the final prototype was developed. The coach confirmed that conducting a third wear trial after the conclusion of the training camp was unnecessary because the new singlets were satisfactory. The manufacturers then started bulk production for the rowing team. According to the request of the coach, approximately 10 singlets were manufactured for each rower as a precaution against singlets being lost, damaged, or stained before

the competition. The final design is shown in Figure 9. Product specifications were kept by the Hong Kong Sports Institute; they recorded detailed information on the new singlets, including construction, size and measurement, fabric types, testing standards, and testing results. This documentation was vital, because any sport team within the organisation could then adopt it as a benchmark for newly developed uniforms in the future. Without detailed product specifications, other research teams might require additional time to source materials and decide on product design and testing standards.

6. Conclusion

A tailor-made approach has long been adopted for evening dresses, wedding gowns, and suits. However, it has rarely been used in the functional wear or active wear markets, and academic research on the subject is limited. In contrast to other commercially available sport clothing, the new singlet design developed in this project is fit for both general use and specific individual needs. The decisions made regarding fabric types, construction, and design details could be implemented in the design of other rowing apparel. The findings of the new design tests, such as the improvement of seam structure and modification of the cut of the singlets, could be used as references by other rowing teams worldwide. Fit preference was a key focus of the research team, because the singlet had to fulfil the individual requirements of each rower and positively influence athletic performance. The application of a 3D body scanner provides designers with measurements that are more efficient but cannot predict individual expectations for garment fit. Hence, the garment technicians' experience was still vital to improving the fit of each singlet. Throughout the wear trials, the athletes could test the singlets and immediately provide valuable feedback to the research team and manufacturer.

A design process framework provided a clear guideline for collaboration among different parties over the course of this project. The research team used the framework to illustrate clear milestones in product development. Every stage of the framework, namely problem definition, creative exploration, and implementation, fully involved all three parties. This project demonstrated the importance of the interactions among the design team, production team, and end users (rowing team). After the first stage of development, all parties agreed that improving rower performance was the priority. Within the allowed budget, the research team explored different possibilities with the rowing team and manufacturer. The effort, cost and time spent on R&D before the announcement of the new singlet were unforeseen but vital.

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