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Designing a Functional Children's Swimming Vest: Creative Process and Evaluation

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Contents

1	Descriptor	3
2	Researcher Profile	4
3	Research Questions	5
4	Research Output	6
5	Research Field & Key References	7
6	Research Methods, Prototypes, & Materials	8
7	Research Outcomes, Findings, & Further Research	22
8	Research Dissemination	27
9	References	28

Designing a Functional Children's Swimming Vest: Creative Process and Evaluation

Descriptor

The use of buoyant swimwear for children has become more common. However, its bulkiness and hardness restrict the wearer's movement. In MCO 1, a new buoyant material using inlay-knitting technology was successfully developed. This study (MCO 2) aims to investigate the design of a buoyant swimming vest for children. It utilises the application of knitted buoyant fabrics to advance another generation of vests that can achieve better fit, comfort, and mobility for the wearer. Prof. Ho led this project, and his responsibilities included research design, methodological development, data analysis and evaluation, and dissemination management.

To test the new design, subjective evaluation was performed using wearer trials to compare the performances of the two samples available in the market. To justify the wearer trial, the FEA Consumer Needs Model was adopted and modified. The results of a paired sample t-test showed that the knitted buoyant swimming vest demonstrates improved functionality and higher buoyancy than the two market samples conforming to British Standard EN13138-1:2014. The results of repeated measures analysis of variance showed an overall significant higher satisfaction level from the knitted buoyant swimming vest than the two market samples in terms of fit, comfort, and mobility. To improve the aesthetic value of the prototypes, the shell of the vest was printed with designs. To ensure the quality of the printing, the effects of UV-curable inkjet printing on physical and aesthetic properties were also evaluated.

The design methodology, details of each part of the vest, and data of its performance are significantly valuable for benchmarking future directions in developing buoyant swimming vests for children. The details related to this study were published in two academic papers and one conference paper, wherein Prof. Ho was the corresponding author.

(285 words)

Personal Profile: Prof. Chupo HO



Associate Professor Chu-po Ho is a researcher specializing in the design of functional sports apparel/textile and the development of related equipment. His research focuses on the integration of cutting-edge knitting technologies, ergonomic design of sports clothing to enhance performance, and creation of innovative 3D-printed structures through modifications in loop-stitch knitting mechanisms.

As Principal Investigator (PI), Professor Ho has submitted three MCOs. In MCO 1, he led a team in creating a flexible buoyant fabric using a modified inlay knitting technique. This fabric is notable for its flexible and bendable qualities, which significantly reduce the bulk of conventional swimming devices. In MCO 2, he advanced this buoyant fabric's application in designing a range of buoyant swimming vests for children. The design features adjustable buoyancy to accommodate varying swimming abilities among children. The development stages of the vests and their ratings from wearer trials were also reported. MCO 3 was a collaborative project funded by the School of Fashion and Textiles and the Research Institute of Sports at The Hong Kong Polytechnic University, amounting to HKD 700,000. In this initiative, Professor Ho directed another team in developing experimental 3D-printed, lattice-structured materials inspired by the high-compression properties of knitted spacer fabrics. This design was applied to bicycle saddles, which are crucial for enhancing rider comfort and performance, per the funding scheme's requirements.

In addition to his research publications, patents, and design registrations, Professor Ho has received international recognition for his work, including the 2024 Red Dot Design Award (Winner in Design Concept) and the Gold Award at the 2022 Inventions Geneva Evaluation Days.

Research Questions

1. What is the design process model for creating a buoyant swimming vest for children?
2. What are the design requirements and details for the construction of the swimming vest when inlay-knitted buoyant fabric is applied as the buoyant medium?
3. What considerations should be taken into account when UV-curable inkjet printing technology is utilised to improve the vest's aesthetic attractiveness?
4. What are the content and assessment methods for subjective measurement when the newly designed swimming vest is compared to market samples (using foam blocks as buoyant material)?
5. To what extent can the newly designed swimming vest perform better for the wearer in terms of overall fit, comfort, mobility, and confidence levels in aiding swimming abilities?

Research Outputs



4 x Design Artefacts

2 x Academic Papers

- Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. 2021. Design of novel buoyant swimming vest using inlay knitting technology, *Textile Research Journal*, 91(9-10)
- Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. 2020. Effect of UV-curable inkjet printing parameters on physical, low-stress mechanical, and aesthetic properties of polypropylene knitted fabrics. *Fibers and Polymers*, 21(12), 2788-2798

1 x Conference Paper

- Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. (2019, September). New thinking in designing buoyant knitted textiles. Paper presented at the 6th International Conference on Arts and Humanities, Kuala Lumpur, Malaysia.

Research Field & Key References

- In recent decades, foam blocks have been used as the main medium to make buoyant swimwear. However, they have been criticized as being extremely bulky due to the lack of distribution in their buoyancy (Meredith, 1995). An increase in the buoyancy of the swimwear inversely affects the horizontal swim distance (Gagnon et al, 2012). Therefore, adjustable buoyancy is needed for the wearer to be able to reduce the buoyancy of the swimwear as their swimming skills develop (Sammann, 1999)
- The high extension and recovery properties of knitted fabrics provide incentive to incorporate them into sportswear, as they can stretch by 15–20% in width without significant yarn extension (Au, 2011). The stretchiness of knitted fabrics allows a knitted garment to mould to the wearer's body, which is important for swimwear. However, it was predicted that fabrics consisting solely of knitting yarn would be insufficiently buoyant.
- The challenge of incorporating buoyant materials can be overcome by using inlaid knitting. This is because the buoyant material can be inlaid into the knitted fabric without forming any loops. This fabric can also be knitted into particular shapes to decrease the number of seams, production time, and fabric waste, as compared with cut and sewn products.
- Although our research team believes that knitted buoyant fabric inlaid with foam rods has a higher buoyancy than that with buoyant tubes (Li et al, 2018, 2020), the related knowledge and design when applying this technology into a real buoyant swimming vest is still unknown.
- In this study, we aimed to apply this inlay knitting fabric in the design of a buoyant swimming vest for children. Subjective measurement was conducted to testify its reliability in product safety (buoyancy) and how it performed better for the subjects in terms of both physical movement and self-confidence in swimming, as compared to the market samples that mainly use foam panels for buoyancy.

Research Methods, Prototypes, & Materials

The design process model is shown in Figure 1. It was specifically created for the design and development of knitted buoyant swimwear for children.

Analysis Stage

- **Problem Identification:** This study is based on the fundamental concept that the development of an exemplary idea requires identifying the problem to meet a certain need as precisely as possible (French, 1999; Kett & Wartzack, 2015). It is important to pinpoint the problem in detail before starting the product development by collecting vital related information, including the standards that the product have to meet and existing constraints and their importance (Pahl et al., 2007). Numerous patents and studies were consequently examined and market research on buoyant swimwear and the major drawbacks of conventional buoyant swimwear were also analysed and reported.

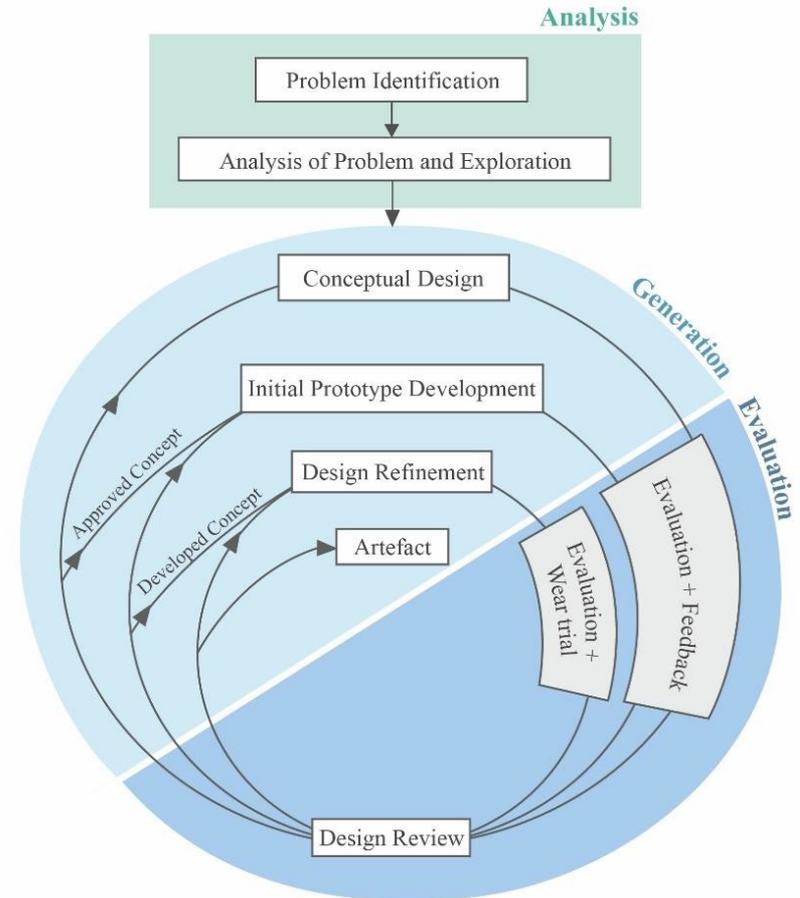


Figure 1. Theoretical design process model of knitted buoyant swimwear for children

Research Methods, Prototypes, & Materials

Analysis of Problem and Exploration

- By studying numerous patents for buoyant swimwear (Mann, 1995; Meredith, 1995; Staver, 2008; Gonsalves & Gonsalves, 2013; Gomez, 2014; Kalayci et al., 2015, Zheng, 2016; Lee, 2017), improvements in conventional buoyant swimwear were analysed and categorised. Possible solutions were proposed accordingly for prototype development (Table 1). Inlay knitting technology can improve the shape retention properties of knitted fabric, as inlaid knitted fabric can bend to the desired curvature without springing back, providing the vest with a better fit to the body.

Table 1. Exploration of knitted buoyant swimming vests

Category	Areas of improvement in patented buoyant swimming vests	Design features of knitted buoyant swimming vests
Fit	1 The buoyant swimsuit is displaced away from the body due to buoyancy. ⁵	1 The shape retention of knitted buoyant fabric may provide a better fit to the wearer's body.
Bulkiness	2 The bulkiness and inflexibility of foam-based buoyant clothing forces the wearer to swim unnaturally or uncomfortably. ⁶	2 Flexible expandable polyethylene foam rods can be inlaid into knitted fabric to reduce the bulkiness and inflexibility of foam.
Buoyancy	3 Foam blocks located around the chest provide uneven distribution of buoyancy. ⁷ 4 The high buoyancy of integrated buoyant swimwear may inversely affect horizontal swim distance. ¹⁴	3 Buoyant materials can be distributed evenly around the upper body. 4 Adjustable buoyancy can be achieved by removing buoyant layers inside the vest.
Donning and doffing	5 It is inconvenient to remove the entire suit in the event of restroom use or a diaper change. ¹¹	5 A vest design may be developed instead of a one-piece swimsuit to facilitate the removal of buoyant swimwear.

Research Methods, Prototypes, & Materials

Generation Stage

- Conceptual design: After the research stage, conceptual designs of buoyant fabric and swimwear were developed based on the physics of buoyancy and knitting technology.
- Initial Prototype Development: During this stage, several preliminary layouts with the specifications were produced (Pahl et al., 2007). The inlaid knitted fabrics with different types of yarns, buoyant materials, and knitted structures were developed. The friction between the inlaid material and the metal component in the knitting machine inhibited the use of a computerized knitting machine.
- Design refinement: The design of the knitted buoyant swimwear was refined for the structural design and outline of the swimwear. After developing the initial swimwear prototypes, the buoyancy and fit were refined.

Evaluation Stage

- The solution variants and overall principle solution have to undergo a comprehensive assessment to determine whether the application of the proposed solution meets the requirements of the goals (Blessing, 2009; Schleinkofer et al., 2018). The evaluation of the individual designs result in the selection of one design that must not only benefit from the others but also be improved by them (Pahl et al., 2007). The inlaid knitted fabrics were evaluated objectively whereas the prototypes were evaluated both objectively and subjectively.

Artefact Stage

- This is the last phase in which aesthetics are considered to enhance the appearance of the product (Başer, 2008). After assessing a variety of different criteria, the final design of the knitted buoyant swimwear for children that can provide sufficient buoyancy with improved functionality was developed.

Research Methods, Prototypes, & Materials

Development of the Knitted Buoyant Fabric Suitable for a Swimming Vest

The inlaid knitted buoyant fabric in this study was knitted with a 1x1 rib structure, using one end of the knitting yarn (250D hollow polypropylene) and one end of the inlaid EPE foam rods, with a diameter of 6.36 mm. The buoyant fabrics were knitted on a 7-gauge V-bed hand-knitting machine.

Importance of Creating Crease Lines for the Knitted Panels

Crease lines in each panel and a reduction in the garment's outer length were found to facilitate the movement of wearers. In the region with the crease line, a single jersey on the back needle bed was made, which allowed the inlaid foam rods to be seen on the front side of the fabric (Figure 2). This facilitated the manual cutting of the foam rods with scissors without cutting the knitted loops at the back of the fabric (Figure 3).

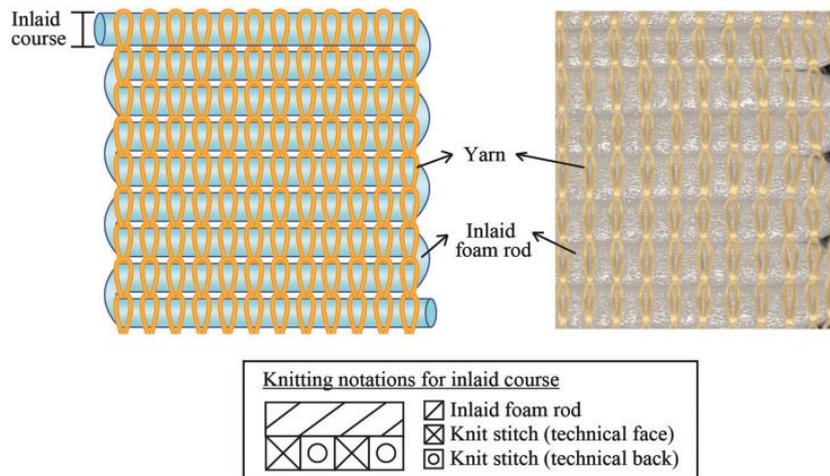


Figure 2. Structural details of the inlaid knitted fabric

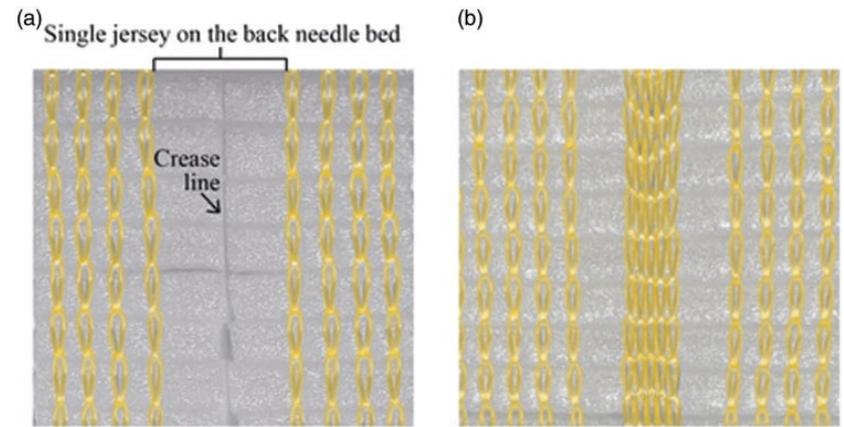


Figure 3. Crease line at the back panel: (a) front view; (b) back view

Research Methods, Prototypes, & Materials

Conceptual Design of Buoyant Swimwear

The swimwear is designed in the form of a vest as it is more convenient for doffing when using the toilet or making a diaper change. According to the literature, crease lines facilitate the movement of wearers (Kim et al., 2015). Therefore, swimwear with a U-neck and crease lines was designed (Figure 4). The inlaid knitted buoyant fabric was knitted to match the garment shape to reduce fabric wastage. Figure 5 shows the fashion illustration for one of the designs (shell layer).

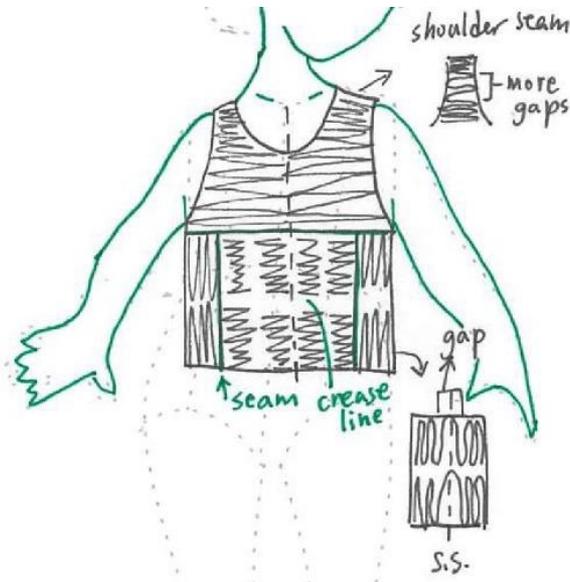


Figure 4. Conceptual design of buoyant swimwear



Figure 5. Illustration of the shell design

Research Methods, Prototypes, & Materials

Inlay Knitted Buoyant Panels in the Vest

After knitting, the foam rods in the knitted fabric were cut at the centre-back in the back panel and at the middle of the waist panel, as shown in Figure 6. Crease lines were made to facilitate bending movements at the waist and back.

A notable benefit of the structure of the inlaid knitting became evident as portions of the inlaid fabric remained connected by the yarn even after the inlaid foam rods were cut (Figure 7).

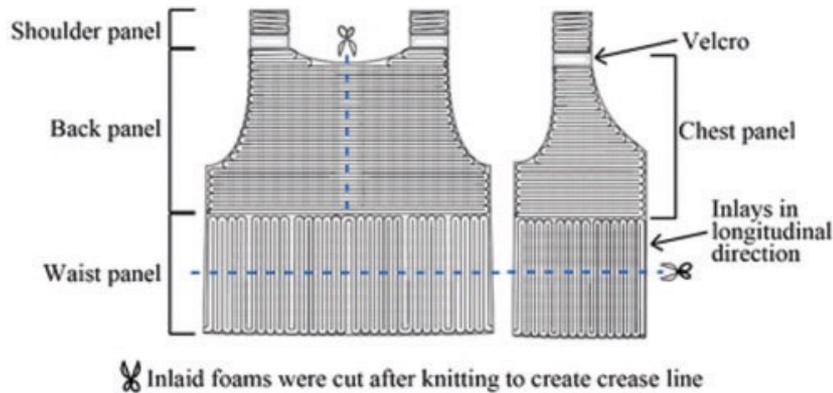


Figure 6. Creation of the crease line on the inlaid knitted buoyant layer



Figure 7. Crease line of the waist panel, created by cutting

Research Methods, Prototypes, & Materials

Construction of the Prototype.

A knitted buoyant swimming vest with a shell was developed (Figure 8). It was a V-neck vest composed of four buoyant layers in the body panel and one layer in the shoulder panels. The knitted vest was developed to match the size of the two market samples used for comparison.

Adjustable Buoyancy and Tapered Edges.

The knitted buoyant layers can be removed individually to enable a range of buoyancy adjustment as the wearer's swimming skills develop. In line with the study by Kim et al. (2015), the reduction in the garment's outer length facilitated the wearer's movement.

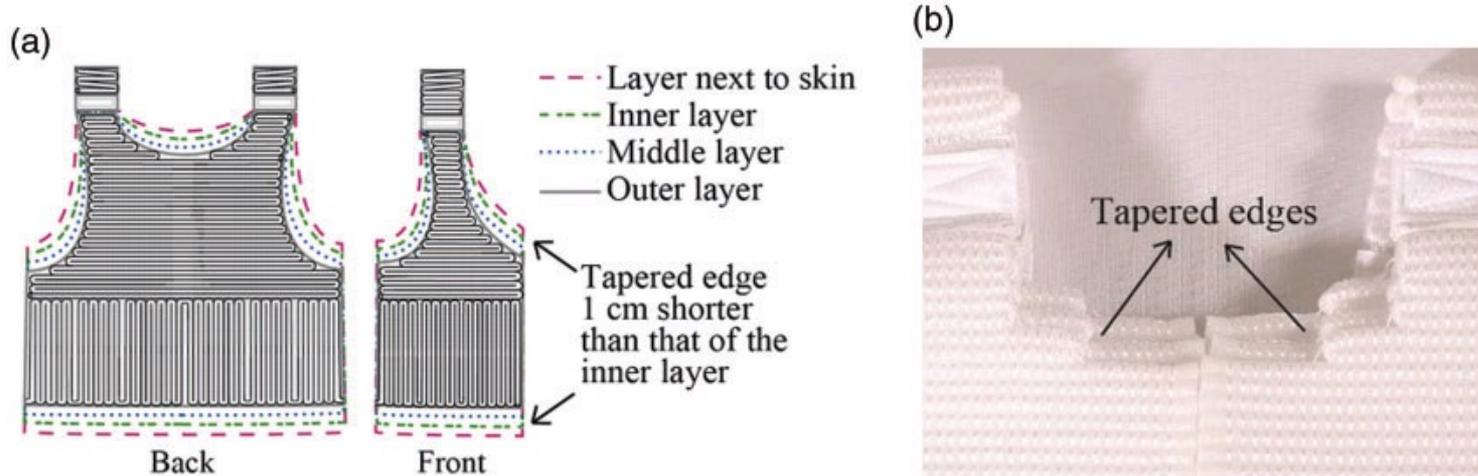


Figure 8. (a) Illustration of the outer and inner inlaid knitted buoyant layers with tapered edges; (b) image of the tapered edges at the back of the neckline

Research Methods, Prototypes, & Materials

Aesthetics of Prototypes

A graphics collection namely “*Connected*” was designed for printing onto the knitted buoyant swimwear. *Connected* explores how we relate to ourselves and others in this world. Four basic elements that contribute to developing our world – society, family, religion, and culture – were selected. The designs were inspired by architectural floor plans and Māori (Polynesian indigenous people) patterns. The graphics (Figure 9) are inspired by the architectural floor plans of the national assembly building of Bangladesh, Casa Luis Barragan (the Luis Barragán House and Studio), La Sagrada Familia (Roman Catholic basilica in Spain (Zukowsky, 2018)), and Māori patterns. The national assembly building of Bangladesh represents society. Casa Luis Barragan represents family. Sagrada Familia represents religious connections. The Māori patterns are commonly used to decorate the public housing of the Māori people (Witehira, 2019) and represent cultural connections. The concrete lines and geometric shapes in the pattern aim to express creativity using basic structures.



Figure 9. Four graphic patterns designed for the swimwear (pattern designed by Li, N.W., supervised by Ho, C.P.)

Research Methods, Prototypes, & Materials

Effect of UV-Curable Inkjet Printing on Aesthetic Properties of Polypropylene Knitted Fabrics

As the use of textile polypropylene (PP) fibres becomes more common in commercial textiles and sportswear, investigating the effects of UV-curable ink on the heat-sensitive PP knitted fabrics is crucial to optimize the pattern design. We investigated the effects of UV-curable ink on the heat-sensitive PP knitted fabrics when the ink was cured using UV light at room temperature, in order to avoid degradation of the PP fabric by high temperature, and provided an alternative colouring method for PP fabric used in sportswear. The influences of printing parameters, such as the printing distance, number of overprints, and colour of ink, on fabrics as well as on aesthetic, physical, and low-stress mechanical properties in terms of tensile, bending, shearing, surface, and compression were systematically investigated.

To study the factors that affect the fabric's aesthetic, physical, and low-stress mechanical properties, the PP fabric was knitted and printed on an inkjet printer with UV-curable ink. The pigment films were analysed via Fourier transform infrared (FTIR) spectroscopy to confirm the curing of the ink. To evaluate the main factor affecting the fabric's physical properties and low-stress mechanical properties, the data obtained from the experiment were analysed using SPSS 23 (IBM Corp., Armonk, New York).

The results indicated that the physical properties and low-stress mechanical properties of PP fabrics printed with UV-curable ink were significantly affected by the number of overprints and the colour of the prints, while the colour appearance was affected mainly by the number of overprints and the printing distance. In terms of the fabric's hand value, only 2HB and 2HG5 were significantly affected by the number of overprints and the colour of the prints, with the prediction rate exceeding 40% among the low-stress mechanical properties. The fabric's hand value was not significantly affected by the thin UV-cured ink film when compared with the fabric itself. Fabric printed in a colour with the greatest lightness and the fewest overprints had the lowest fabric weight, thickness, and colour difference (ΔE) compared to the reference colour, in addition to better bending recovery and resilience properties.

Research Methods, Prototypes, & Materials

The chemical changes in the cured ink films were analysed by the reflectance peaks, which represent the functional groups at certain wavenumbers according to their transmittance values.

Studies of UV-cured acrylates have reported that curing occurs via the decrease and disappearance of the vibration peaks of the C=C double bonds.

The absorption peaks of vibration of the C=C double bond appear at 810, 840, and 950 cm^{-1} , stretching over the range of 1410 to 1420 cm^{-1} .

In Figure 10, the decrease and disappearance of the twisting peak at 810 cm^{-1} and the stretching peak at 1410 cm^{-1} reveal that polymerization occurred after the UV-curing process.

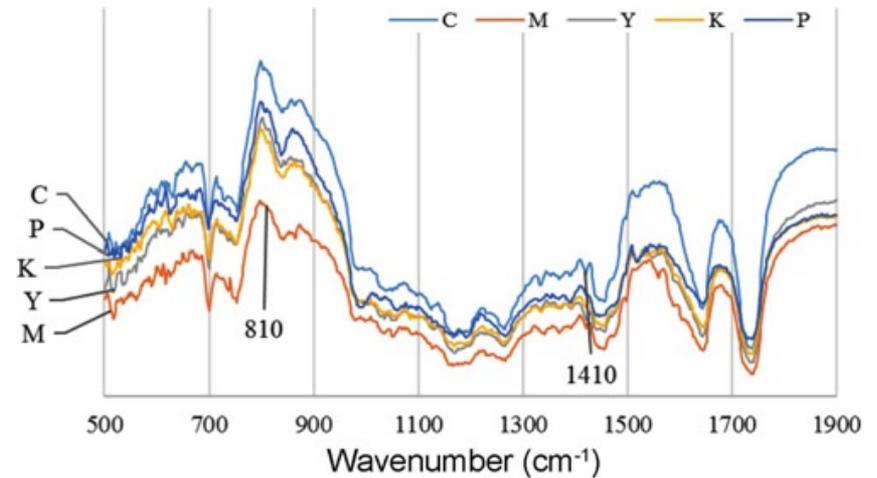


Figure 10. Fourier transform infrared analysis of the pigmented films prepared with C, M, Y, K, and Pantone P115-4C (P) formulations

Research Methods, Prototypes, & Materials

The results (Table 2 & Figure 11) showed that the printing machine obtained the best printing results with the shortest printing distance when the number of overprints was set to one. In this study, the number of overprints was set to two when evaluating the effects of printing distance on a fabric's properties. A larger amount of ink was released, but not all the ink droplets could be deposited on the fabric surface and cured successfully when the printing distance increased. Therefore, the colour that appeared on the fabric was lighter than that with the shortest printing distance and had the most similar lightness to and least colour difference from the reference colour. Moreover, the loss of ink droplets had a noticeable effect on the appearance of colour but did not have a significant effect on the physical and mechanical properties of the printed fabric.

Table 2. Colour parameters and differences of fabrics

Code	Number of overprints	Printing distance (mm)	L^*	a^*	b^*	ΔL^*	Δa^*	Δb^*	ΔE
Pantone P115-4C	-	-	83.48	-11.83	-12.01	-	-	-	-
B1	1	98.90	77.79	-8.25	-12.23	-5.45	3.41	-0.24	6.43
B2	2	98.90	69.42	-15.75	-15.40	-13.81	-4.09	-3.41	15.09
B3	3	98.90	65.83	-14.90	-21.80	-17.40	-3.24	-9.81	20.25
B4	2	96.90	69.90	-14.09	-17.25	-13.33	-2.43	-5.26	14.54
B5	2	94.90	76.33	-10.00	-12.55	-6.91	1.66	-0.56	7.17
O	Unprinted	-	85.61	-1.08	-0.79	-	-	-	-

L^* : lightness coordinate, a^* : green/red coordinate orientation; redness ($+a^*$); greenness ($-a^*$), b^* : blue/yellow coordinate orientation; yellowness ($+b^*$); blueness ($-b^*$), ΔE : color difference between the reference color and fabric samples, ΔL^* : lightness difference between the reference color and fabric samples, Δa^* : difference in green/red intensity between the reference color and fabric samples, Δb^* : difference in blue/yellow intensity between the reference color and fabric samples.

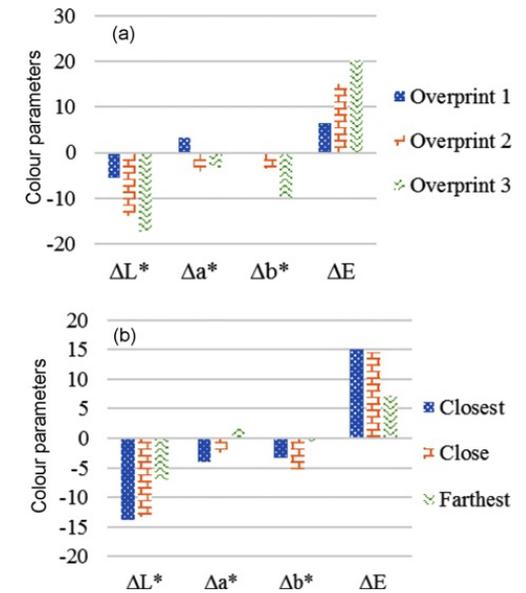


Figure 11. Colour measurements of fabric samples with varying (a) number of overprints and (b) printing distances

Research Methods, Prototypes, & Materials

- Different Versions of Prototype Development

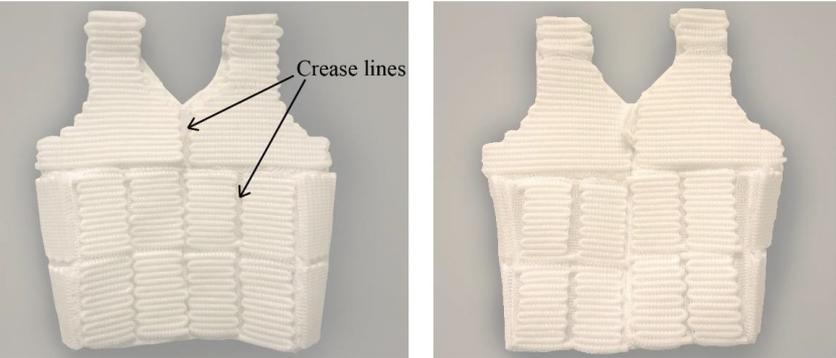


Figure 12. Version 1: front view (L) and back view (R)



Figure 13. Version 2: front view (L) and back view (R)



Figure 14. Version 3 (adjustable buoyant layers): front view (L) and back view (R)



Figure 15. Version 4 (adjustable buoyant layers): front view (L) and back view (R)

Research Methods, Prototypes, & Materials

Appearance of Prototype Version 5 (Final Version)

Figures show the front view, back view, and the swimming vest worn by one of the subjects (Figure 16).



Figure 16. Knitted buoyant swimming vest: (a) front view; (b) back view; (c) the swimming vest worn by one of the subjects

Research Methods, Prototypes, & Materials

Figure 17. Adjustable buoyancy by removing the inlay knitted buoyant panels either at the front or back, depending on the needs of the wearer



(a)



(b)



(c)



(d)

Figure 18. The mini-collection of the 5th version

Research Outcomes, Findings, & Further Research

Building on our prior development of a low-bulk buoyant fabric via inlay knitting technology, this study pioneers an adjustable-buoyancy swimsuit for children. The design overcomes key market limitations through:

- a modular buoyancy system enabling progressive reduction as swimming skills advance;
- ergonomic construction maximizing movement freedom while ensuring safety; and
- confidence-centric features promoting skill acquisition through controlled flotation support.

This represents the first integration of dynamic buoyancy control within a seamless textile platform.

Validation employing a mixed-methods protocol included:

- Objective buoyancy testing to confirm precise flotation adjustment
- Comparative wear trials with target users, which demonstrated significant improvements over commercial products in mobility and comfort levels
- Quantitative analysis of questionnaire data and performance metrics to validate the design's functional efficacy

Research Outcomes, Findings, & Further Research

Objective Measurement Result

For the testing, two market samples (A & B) (Figure 19) were purchased for comparison to the newly designed prototypes.

According to the British Standard EN13138-1:2014, a buoyant garment made for swimming must have a minimum buoyancy of 20N for a wearer with 18–30 kg body mass aged between 3 and 6 years. When testing the mechanical properties in Clause 5.5, the material sample should lose no more than 10% of its original buoyancy.

Three garments passed these standards and were thus used for comparison for the wearer trials (Table 3).



Figure 19. Two market samples (A & B) used for comparison

Clause	Testing item	Results		
		Knitted buoyant vest	Market Sample A	Market Sample B
5.2	Buoyancy			
5.2.1	Buoyancy characteristics of the complete device	Pass	Pass	Pass
	Buoyant force of the complete device (N)	30.9	27.8	25.8
5.5	Materials: mechanical properties			
5.5.2	Resistance to puncturing	Pass	Pass	Pass
	Buoyancy loss (%)	6.5	6.0	5.2

Table 3. Results of the buoyancy test according to British Standard EN13138-1:2014

Research Outcomes, Findings, & Further Research

Questionnaire

The questionnaire was developed based on the published functional apparel studies and the FEA model (Labat & Delong, 1990; Stokes & Black, 2012; Kim et al., 2015; Michaelson et al., 2018). The functional criteria of the FEA model – including fit, mobility, comfort, and donning and doffing – were employed as the basis for the questionnaire. The wearer's confidence level was also included in this study to investigate the effect of buoyant vests on the improvement of their confidence in water.

Three types of buoyant vest were evaluated in three stages of evaluation of the buoyant vest design regarding (a) fit, (b) comfort, and (c) mobility. Feedback from the 12 participants was obtained using a five-point Likert scale.

To analyse the satisfaction of comfort, the questionnaire included the following: (a) ability to retain warmth, (b) stiffness of garment, (c) overall comfort, and (d) level of confidence while swimming in water with the buoyant swimwear (Lamb & Kalall, 1992; Michaelson et al., 2018; Park & Hahn, 2014). Satisfaction regarding the displacement of the vest from the shoulder due to buoyancy was also evaluated (Kim et al., 2015). The evaluation of mobility included the freedom of arm movement, waist movement, and movement while swimming as well as the ease of donning and doffing after swimming (Kim et al., 2015; Michaelson et al., 2018) (Figure 20).



Figure 20. Wear trial: wearing the knitted buoyant vest (a) out of water in waist flexion position; (b) in water

Research Outcomes, Findings, & Further Research

The data from the subjective wear trial experiment were analysed using SPSS 23. A paired-sample t-test was conducted to analyse any significant differences between the tightness value in and out of water. A repeated measures analysis of variance (rANOVA) was conducted to compare the ratings of satisfaction between the dependent variables (satisfaction of fit, comfort, and mobility) and the independent variable (types of buoyant vests) (Table 4). Prior to the rANOVA, the data were screened to ensure that the test's assumptions were met. Descriptive statistics, histograms, Q-Q plots and the measures of skewness and kurtosis indicated that the distribution of the dependent variables was close to a normal curve. The assumption of sphericity and equality of variance was fulfilled. The significance level of the statistical analysis was set at 0.05.

Condition	Category	Evaluation ^a	Knitted buoyant vest		Market Sample A		Market Sample B		F	p value
			Mean	SE	Mean	SE	Mean	SE		
Out of water	Fit	Neck	3.92	0.31	3.58	0.26	3.42	0.23	1.32	0.31
		Shoulder	4.08	0.31	3.50	0.26	3.50	0.20	3.13	0.09
		Waist	3.75	0.28	3.58	0.19	2.00	0.28	17.64	0.00
		Tightness ^b	2.67	0.19	2.58	0.15	4.58	0.19	40.79	0.00
	Overall fit		3.75	0.31	3.50	0.29	2.17	0.27	5.62	0.02
		Warmth	4.00	0.25	3.92	0.23	3.67	0.14	0.56	0.59
		Stiffness	3.92	0.23	3.50	0.26	2.17	0.37	9.40	0.01
	Overall comfort		4.33	0.26	3.67	0.19	2.00	0.28	10.68	0.00
		Confidence in water after wear	4.00	0.21	3.58	0.19	3.75	0.13	3.79	0.06
		Freedom of arm movement	4.67	0.14	4.17	0.11	3.67	0.19	10.71	0.00
Freedom of waist movement		4.50	0.15	4.00	0.25	2.58	0.43	7.79	0.01	
In water	Fit	Neck	3.42	0.29	3.17	0.30	3.50	0.20	0.46	0.65
		Shoulder	3.50	0.26	3.42	0.23	3.50	0.20	0.10	0.91
		Waist	3.00	0.25	3.42	0.23	2.75	0.22	2.30	0.15
		Tightness ^b	2.17	0.11	2.33	0.23	4.42	0.19	74.78	0.00
	Displacement of vest from wearer's shoulders due to buoyancy		2.75	0.22	2.58	0.29	3.75	0.22	4.20	0.05
		Overall fit	3.00	0.21	2.83	0.27	2.58	0.26	0.94	0.42
		Warmth	3.75	0.28	3.58	0.19	3.58	0.19	0.22	0.81
	Overall comfort		4.00	0.28	3.33	0.28	2.17	0.37	15.28	0.00
		Confidence in water after wear	4.50	0.15	3.92	0.15	3.92	0.15	7.42	0.01
	Freedom of swimming		4.42	0.15	3.67	0.23	3.58	0.19	18.08	0.00
		Ease of donning and doffing	4.67	0.14	4.00	0.17	3.25	0.25	15.73	0.00

^aFive-point Likert scale (1 = extremely dissatisfied to 5 = extremely satisfied), except where indicated.

^bFive-point rating scale: 1 = too loose, 2 = loose, 3 = moderate, 4 = tight and 5 = too tight.

SE: standard error.

Table 4. Results of satisfaction ratings and the repeated measures analysis of variance of the knitted buoyant vest and market samples

Research Outcomes, Findings, & Further Research

Fit Satisfaction:

The results showed an overall significantly higher level of satisfaction with the knitted buoyant vest than with Market Sample B in terms of waist and overall fit out of water. This may be explained by considering that the buoyant inlaid knitted fabric retains the body shape of the wearer and improves the overall fit. In terms of neck fit, shoulder fit, waist fit, and the overall fit in water, there was no significant difference reported between the knitted buoyant vest and the two market samples, which shows that the knitted vest yielded the same high satisfaction as the market samples.

Comfort Satisfaction:

Participants in this study were significantly more satisfied with the overall comfort of the knitted buoyant vest, both in and out of water (out of water: mean.4.33, in water: mean.4.00). Participants reported that the knitted buoyant vest was the most comfortable vest both in and out of water, followed by Market Samples A and B. Participants reported higher confidence in water by 0.58 points while wearing the knitted buoyant vest than they did wearing Market Samples A and B. This implies that the knitted buoyant vest improved the wearer's confidence in water better than the market samples.

Mobility

Participants reported the highest levels of satisfaction in freedom of arm movement out of water, freedom of swimming, and ease of donning and doffing after wearing the knitted buoyant vest in water, followed by Market Sample A and Market Sample B. Moreover, wearer satisfaction regarding waist movement while wearing the knitted buoyant vest (mean.4.50, SE.0.15) was 1.92 points higher than that associated with Market Sample B (mean.2.58, SE.0.43) and elicited similar satisfaction to Market Sample A. This may be because the crease lines in the knitted buoyant layer inside the knitted buoyant vest facilitated bending at the waist, as opposed to the bulky foam rod in Market Sample B.

Research Dissemination

- **Academic Journal Articles**

- Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. 2021. Design of novel buoyant swimming vest using inlay knitting technology, *Textile Research Journal*, 91(9-10) (<https://doi.org/10.1177/0040517520975632>)
- Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. 2020. Effect of UV-curable inkjet printing parameters on physical, low-stress mechanical, and aesthetic properties of polypropylene knitted fabrics. *Fibers and Polymers*, 21(12), 2788-2798 (<https://doi.org/10.1007/s12221-020-1295-5>)

- **Conference Paper**

- Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. (2019, September). New thinking in designing buoyant knitted textiles. Paper presented at the 6th International Conference on Arts and Humanities, Kuala Lumpur, Malaysia. (<https://www.researchgate.net/publication/341508777> New Thinking in Designing Buoyant Knitted Textiles)

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