Design and Development of Functional & Protective Medical Wear

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Abstract—**Medical professionals endure physically demanding 8–12hour shifts with constant exposure to bodily fluids, chemicals and infectious agents. Current hospital uniforms, predominantly poly-cotton scrubs, fail to provide adequate protection, breathability, and ergonomic comfort. This paper presents the design and development of SHIFT-ARMOR, a functional and protective medical uniform that integrates antimicrobial and liquid-repellent finishing treatments with ergonomic panel construction. An ethnographic study was conducted across four hospitals to identify specific comfort, hygiene, and mobility deficiencies in existing workwear. Based on these findings, five concept scrub designs were proposed; the Flow Flex Scrub design was developed through participatory evaluation. Fabric testing confirmed the effectiveness of a neem-extract antimicrobial combined with Nikwax TX Direct Wash-In liquid repellent finishing. Wear tests with nine medical interns and nurses validated improved comfort, fabric performance, and overall design functionality. The study demonstrates that integrating protection, breathability, and ergonomic design into a single medical uniform system is feasible and highly desirable for healthcare professionals.**

Index Terms—**Antimicrobial finishing, ergonomic design, functional workwear, healthcare uniforms, liquid repellency, medical scrubs, protective textiles.**

I. INTRODUCTION

Medical professionals, including nurses, interns and hospital staff operate in high-intensity clinical environments for extended shifts ranging from 8 to 12 hours. These settings involve constant physical movement, proximity to various infectious agents, and repeated exposure to bodily fluids and chemical disinfectants. Despite these demanding conditions, the uniforms worn by healthcare workers have changed little over decades with most institutions relying on standard poly-cotton scrubs that prioritize cost over functional performance.

The consequences of inadequate medical workwear are tangible: research has documented microbial colonization of hospital uniforms during normal use [1], and traditional fabrics readily absorb fluids and retain pathogens [2]. Beyond infection risk, current scrub designs frequently contribute to physical discomfort, heat retention, restricted mobility, and rapid fatigue—factors that can impair healthcare delivery and worker well-being.

This paper presents the research, design process, and evaluation of SHIFT-ARMOR: Functional Protective Medical Wear for Long-Hour Shifts. The project aims to engineer a medical uniform that simultaneously addresses antimicrobial protection, liquid repellency, breathability, and ergonomic freedom of movement, while remaining durable, low-maintenance, and suitable for daily hospital use. The work combines ethnographic field research, textile finishing experimentation, iterative concept designs, and structured user evaluation to arrive at a validated prototype suitable for healthcare settings.

II. AIM AND OBJECTIVES

A. Aim

To design and develop a functional and protective medical uniform that enhances comfort, mobility, and hygiene for medical professionals working long hour shifts, while remaining durable, having low-maintenance, and suitable for daily hospital use.

B. Objectives

- To conduct an ethnographic study on uniforms currently available to medical professionals and identify usability and functional problems.

- To develop conceptual uniform designs addressing the identified gaps.
- To source fabric, apply required finishing treatments, and test fabric performance.
- To construct the final garment and collect user feedback through wear testing.
- To document the entire design and development process.

III. RIVIEW OF LITERATURE

A growing body of textile and infection-control research underscores the inadequacy of conventional hospital uniforms in modern healthcare environments. Studies have established that standard hospital uniforms become colonized by microorganisms during routine use [1]. Traditional cotton and poly-cotton fabrics lack protective coatings and are highly absorbent, enabling fluid penetration and microbial retention on the garment surface [2].

Research into antimicrobial scrubs has produced equivocal results when relying on antimicrobial agents alone, suggesting that textile-level antimicrobial therapy must be combined with appropriate fabric structures and surface finishing processes for clinical effectiveness [3]. Natural antimicrobial agents—particularly silver, copper, zinc, and plant-based extracts such as neem—have been found effective when integrated with suitable fabric substrates [4][5]. Neem (Azadirachta indica) has demonstrated antibacterial properties against both gram-positive and gram-negative organisms and has been successfully applied to cotton textiles to impart durable antimicrobial performance [2][6].

Literature specifically emphasizes the need to combine liquid-repellent finishes with antimicrobial agents in healthcare workwear [7]. Durable water-repellent (DWR) treatments such as fluorocarbon and silicone-based systems, along with newer wash-in formulations, can significantly reduce fluid absorption and surface contamination. Research also notes that ergonomic fabric design—incorporating stretch panels and breathable constructions—is essential for long-duration occupational wear [8].

A critical gap identified in the literature is the absence of any existing uniform solution that integrates antimicrobial protection, liquid repellency, breathability, and ergonomic construction in one complete and commercially viable system. The present project aims to bridge this gap.

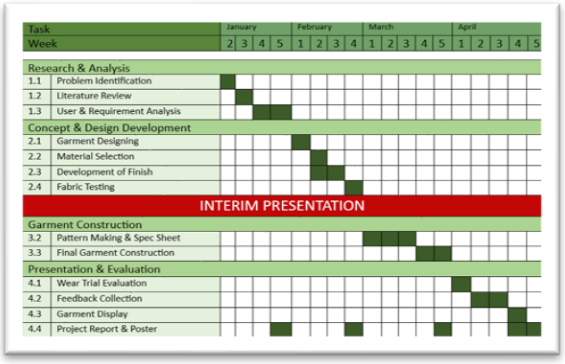
IV. RESEARCH GAP

Existing medical uniforms focus on basic functionality but fail to integrate antimicrobial protection, liquid repellency, breathability, and ergonomic mobility in one complete system. Affordable solutions suitable for long shifts are also limited.

V. METHODOLOGY

The research and design process followed a structured, iterative methodology comprising the following stages:

A. Project Timeline



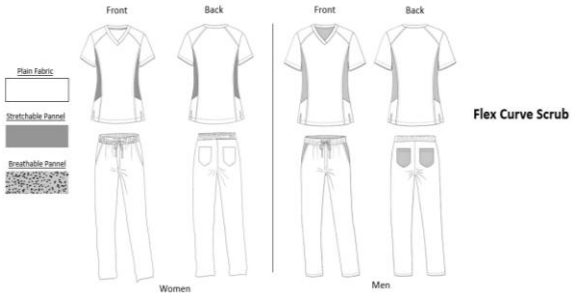
B. Ethnographic Study

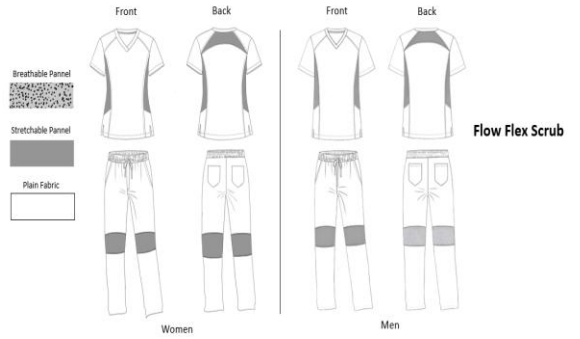
Field visits were conducted to four hospitals in Bengaluru, India. Medical professionals were approached directly and requested to complete structured survey forms. Informal interactions and observational notes supplemented the survey data. The study focused on healthcare professionals wearing scrubs during long clinical shifts in high-exposure, high-mobility environments.

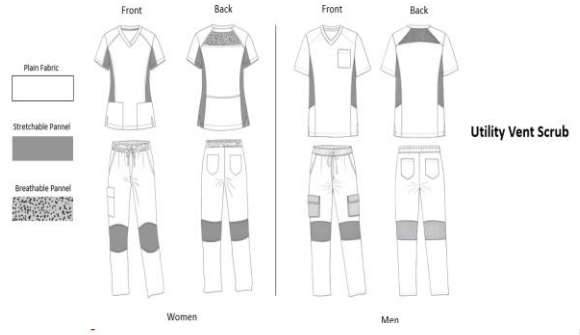
Fig. 1 Ethnographic Survey and Field Observation

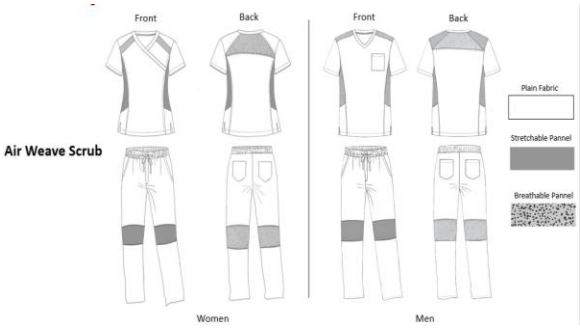
C. Concept Development

Based on ethnographic findings, five scrub concepts were developed: Flex Curve Scrub, Flow Flex Scrub, Utility Vent Scrub, Air Weave Scrub, and Zen Motion Scrub. Each concept incorporated combinations of breathable panels, stretchable panels, and plain fabric zones to address identified ergonomic requirements. There were 60 participants who evaluated all five designs, and the Flow Flex Scrub was selected as the finalized concept for development.









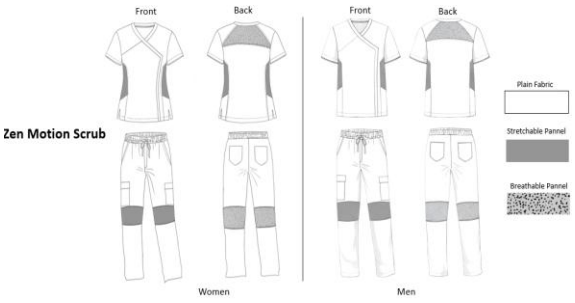


Fig. 2 Initial Concept Sketches

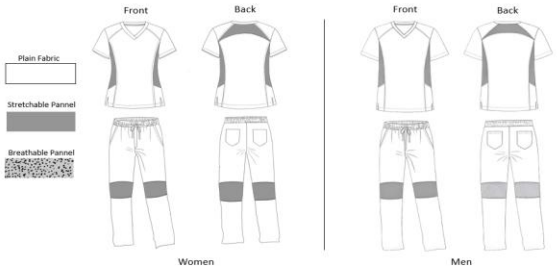


Fig. 3 Finalized Concept Sketch (Flow Flex Scrub)

Fig. 4 CLO 3D Prototype Visualization of Finalized Flow Flex Scrub

D. Material Sourcing and Finishing

Cotton fabric (180 GSM) and jersey knit fabric were sourced for prototype development. An antimicrobial and liquid-repellent finishing treatment was applied using neem leaf extract as the natural antimicrobial agent and Waterproofing Wash-In as the liquid-repellent formulation. The process involved preparing a neem extract solution in distilled water, immersing

fabric samples, and subsequently applying the waterproofing treatment.

Fig. 5 Sourcing

Fig. 6 Antimicrobial Finish

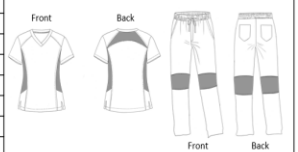
Fig. 7 Water Repellent Finish

E. Fabric Testing

Two key tests were conducted before and after finishing: Crease Recovery Test and GSM & Thickness Test. The crease recovery test was used to evaluate the dimensional stability of the fabric following finishing treatment. GSM and thickness measurements quantified the weight gain attributed to the finishing application. A Water Repellence Test was finished at the textile unit to asses resistance to liquid penetration. The fabric showed hydrophobic behavior, with water forming droplets and rolling off the surface, conforming liquid – repellent performance.

F. Garment Construction and Specification

Final garments were constructed for both women (Style MDWS01) and men (Style MDMS01) based on finalized spec sheets. Women's sizing ranged from XS to L with a sleeveless top and coordinating pants; men's followed equivalent specifications with adjusted measurements. Construction used cotton and jersey materials with zipper and elastic trim details.

Garment Specification Sheet			
Style Name: MDWS01		Date: 20/03/2026	
Category: Women		Size Range: XS,S,M,L	
Season: Spring/Summer		Designer Name: Aditi Jayaswal	
Description: Sleeveless Top With A-line Semi Formal Skirt			
Sl. No	Measurements	In Inch	Flat sketch
1	Full Length Top	23.5	
2	Bust Round	34	
3	Sleeves	6.5	
4	Neck Depth	7	
5	Shoulder Length	14	
6	Full Length Pant	39	
7	Waist Round	28	
8	Hip Round	36	
Wash Care Instruction		Wash with Luke warm water	
Fabric		Cotton, Jersey Material	
Trims and accessories		Zip, Elastic	
Remarks		Scrub with stretchable panels	

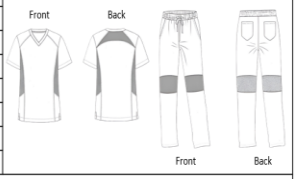
Garment Specification Sheet			
Style Name: MDMS01		Date: 20/03/2026	
Category: Men		Size Range: XS,S,M,L	
Season: Spring/Summer		Designer Name: Aditi Jayaswal	
Description: Sleeveless Top With A-line Semi Formal Skirt			
Sl. No	Measurements	In Inch	Flat sketch
1	Full Length Top	28	
2	Chest Round	40	
3	Sleeves	9	
4	Neck Depth	8.5	
5	Shoulder Length	18.5	
6	Full Length Pant	42	
7	Waist Round	34	
8	Hip Round	40	
Wash Care Instruction		Wash with Luke warm water	
Fabric		Cotton, Jersey Material	
Trims and accessories		Zip, Elastic	
Remarks		Scrub set with stretchable panels	

Fig. 8 Specification Sheet of Final Garment

G. Wear Testing

Nine medical professionals—including medical interns, staff nurses, and student nurses—wore the garments during their actual clinical shifts (6–10 hours) and provided structured feedback on four parameters: overall fit and comfort, overall fabric performance, overall design and functionality, and product recommendation likelihood.

Fig. 9 Wear Test

VI. RESULT AND DISCUSSION

A. Ethnographic Study Findings

Participants were medical professionals working 6–8hour shifts (majority) across 5–6 working days per week. Key findings are summarized below:

- Current uniform: Most participants wore poly-cotton uniforms; comfort was rated as moderate.
- Movement restriction: The majority reported movement restriction during bending, lifting, and extended walking.
- Heat and sweating: Participants reported heat retention and sweating during extended wear.
- Fluid exposure: Frequent exposure to bodily fluids and chemical disinfectants was reported.
- Liquid absorption: Existing uniforms were found to absorb liquids easily and provided inadequate protection against contamination.
- Odor and freshness: Participants expressed a strong preference for uniforms that remain fresh and odor-free throughout shifts.
- Lightweight and easy care: Lightweight, breathable, moisture-managing fabric was the most desired improvement.
- Body fatigue: Discomfort was most frequently reported at the back, shoulders, and underarms.
- Antimicrobial finish: Participants were willing to wear uniforms with antimicrobial and liquid-repellent finishes.
- Price expectation: Most participants expected the uniform to be priced around Rs. 1500.
- Design preference: The Flow Flex Scrub design was preferred by most participants for visual appeal, comfort, ease of movement, and suitability for long active shifts.

B. Fabric Testing Results

Test	Parameter	Before Finishing	After Finishing
Crease Recovery	Cotton (angle / recovery)	145° / 80%	135° / 75%
GSM & Thickness	GSM / Thickness / Weight	180 g/m² / 0.40 mm / 1.80 g	195 g/m² / 0.43 mm / 1.95 g

Table I: Fabric Testing Results (Cotton) Before and After Finishing

The crease recovery test showed a slight reduction from 145° (80% recovery) to 135° (75% recovery) post-finishing, indicating a minor decrease in wrinkle resistance attributable to the finishing treatment. The GSM and thickness measurements increased from 180 g/m² and 0.40 mm to 195 g/m² and 0.43 mm respectively, confirming successful deposition of the finishing agents onto the fabric substrate. The increase in GSM also confirms that the neem and Nikwax treatments were effectively retained in the fabric structure, enhancing protective properties while maintaining acceptable comfort levels for scrub use.

Fig. 10 Fabric Testing Process and Results

C. Cost Analysis

The total production cost for the women's prototype (MDWS01) was calculated at Rs. 4,490, and for the men's prototype (MDMS01) at Rs. 4,645. Key cost components included fabric (cotton and jersey), trims (cord, zipper, elastic), finishing treatment (Nikwax and neem leaves), design charges, stitching, and profit margin. The relatively higher cost compared to participant price expectations (Rs. 1,500) highlights

the need for process optimization and bulk production economies for commercial viability.

D. Wear Test Results

Nine medical professionals participated in the wear test, wearing the SHIFT-ARMOR prototype during actual hospital shifts of 6–10 hours. Post-wear structured feedback was collected across four evaluation parameters. Participants rated the garment positively on overall fit and comfort, fabric performance during extended wear, design and functional utility, and recommendation likelihood. Key observations indicated that the Flow Flex Scrub construction with stretchable panels significantly improved ease of movement compared to standard poly-cotton scrubs, and the finishing treatment was perceived to contribute to garment freshness over the shift duration

VII. CONCLUSION

This project successfully demonstrated the design and development of a functional and protective medical uniform—SHIFT-ARMOR—addressing the documented shortcomings of conventional healthcare workwear. The ethnographic study provided granular, field-validated insights into the comfort, hygiene, and mobility deficiencies experienced by medical professionals during extended clinical shifts. These insights directly informed the five scrub concept designs, of which the Flow Flex Scrub was selected through participatory evaluation as the most preferred design for comfort, ease of movement, and visual appeal.

Fabric testing confirmed that the combined neem-extract antimicrobial and Nikwax liquid-repellent finishing treatment was successfully applied, evidenced by increases in GSM and fabric thickness. The slight reduction in crease recovery post-finishing is a minor and acceptable trade-off given the significant gains in protective performance. Wear test feedback from nine medical professionals validated the prototype across comfort, fabric performance, and functional design dimensions.

The study conclusively establishes that integrating antimicrobial protection, liquid repellency, breathability, and ergonomic panel construction into a single medical uniform system is technically feasible and highly valued by end users. Future work should explore cost optimization strategies for commercial production, investigate more durable finishing application methods for extended wash durability, and expand wear testing to larger and more diverse healthcare worker populations.

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