Media Kesehatan Masyarakat Indonesia
Volume 17 Issue 3 2021
Website : http://journal.unhas.ac.id/index.php/mkmi

Innovation on Preventing the Covid-19 Spread Using "Cool" Personal Protective Clothing for Healthcare Workers

Inovasi Pakaian Pelindung Diri "Sejuk" untuk Tenaga Kesehatan Sebagai Upaya Pencegahan Penularan Covid-19

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ARTICLE INFO

eISSN: 2356-4067
DOI:10.30597/mkmi.v17i3.17847
Published online Sept, 2021

Keywords:
Healthcare workers;
COVID-19;
personal protective clothing;
ice pack;

Kata Kunci:
Tenaga kesehatan;
COVID-19;
pakaian pelindung diri;
kantong es;

ABSTRACT

Healthcare workers need Personal Protective Equipment (PPE) that can protect them, to be safer and more comfortable with handling COVID-19 patients. One important PPE is the Personal Protective Clothing (PPC), where the PPC design has to comply with regulatory requirements, in terms of application, safety, comfort, and cost. A disadvantage is that PPC can be hot and poorly ventilated. The objective of innovation research was to developed a new design of PPC with safe, cool, and comfortable personal protective clothing. PPC is made with 100% polyester coverall according to WHO standards and with ice pack design. This product was subsequently analyzed for material morphology and penetration (water-repellent). Further, relevant information was captured from 14 participants in several health professions, using questionnaires. The laboratory test results of the sample materials reportedly surpassed the specifications and were also incorporated into level-3 PPC. Based on the survey data, the personal protective clothing with ice pack was simple, comfortable, and not hot to use for healthcare workers.

ABSTRAK

*Tenaga kesehatan membutuhkan Alat Pelindung Diri (APD) yang dapat melindungi diri, agar lebih aman dan nyaman saat menangani pasien COVID-19. Salah satu APD yang penting adalah Pakaian Pelindung Diri, desain pakaian pelindung diri harus memenuhi syarat peraturan penggunaannya antara lain, tingkat keamanan penggunaan, kenyamanan dan biaya. Salah satu kekurangan pada pakaian pelindung diri adalah rasa panas saat penggunaan dan kurangnya ventilasi udara. Tujuan dari pembuatan inovasi pakaian pelindung diri ini adalah membuat desain baru pakaian pelindung yang aman, sejuk dan nyaman saat digunakan. Pakaian pelindung diri terbuat dari bahan polyester 100% tipe terusan (*coverall*) sesuai standar dari WHO dengan penambahan desain kantong es (*ice pack*). Bahan dilakukan uji morfologi dan penetrasi bahan (*water repellent). *Selanjutnya pakaian pelindung diri di uji coba oleh 14 responden dari beberapa profesi tenaga kesehatan, menggunakan kusioner. Hasil uji laboratorium bahan sampel melampaui spesifikasi dan termasuk pakaian pelindung diri level 3. Berdasarkan data survei, pakaian pelindung diri dengan kantong es sederhana, nyaman dan sejuk digunakan oleh petugas kesehatan.*

INTRODUCTION

Indonesia first reported COVID-19 cases on March 2, 2020.[1] It spread fast across the community, particularly among healthcare workers because medical facilities (i.e., clinics, health centers, and hospitals) are highly vulnerable. Coronavirus is mainly transmitted through the respiratory tract with specific symptoms of cough, fever, flu, breathing difficulties, anosmia (loss of smell), shortness of breath, and spotting or pneumonia infiltrates in the lungs.[2] This viral infection is possibly due to droplets or direct hand-to-hand contact.[3] Person-to-person transmission has also been reported in healthcare workers.[4]

Healthcare workers who care for COVID-19 patients in hospitals and quarantine centers are at high risk of getting infected, which is confirmed by a high viral load found in the blood due to frequent contact with patients.[5] WHO reported that transmission to clinical staff reached 3000 cases. Meanwhile, 989 medical personnel worldwide died by May 7, 2020.[3] Other data from the Center for Disease Control and Prevention (CDC) reported that approximately 11% of COVID-19 cases infected Healthcare workers.[6] A study found that uninfected healthcare workers wore protective clothing more frequently than the infected ones.[7] A major risk factor for the rapid spread of infection is compliance with stipulated professional standards of the use of Personal Protective Equipment (PPE), including Personal Protective Clothing (PPC), eye goggles, and masks or respirators. Therefore, the effective use of personal protective clothing for healthcare workers will reduce the risk of COVID-19 transmission.[8] Personal Protective Clothing (PPC) is among the standard protective equipment to evade COVID-19 infection.[9]

The use of PPC is mandatory for health workers. However, various factors including the inconvenience (e.g., the discomfort of wearing, heat) and the insufficiency (i.e., repeated use) can lead to non-optimal utilization.[10] For the long-term use, the healthcare workers can suffer from overheating or can fall unconscious.[11] Those problems could influence the performance and reduce productivity. Therefore, a better solution for easy-to-install and detachable equipment is needed.

The first objective of this study is to initiate innovations of personal protective clothing (i.e., cool and comfort) for healthcare workers to prevent COVID-19 infection. Second, the productivity of manufacturing SMEs should be increased to focus on generating decontaminated fabrics to meet high PPE demands.

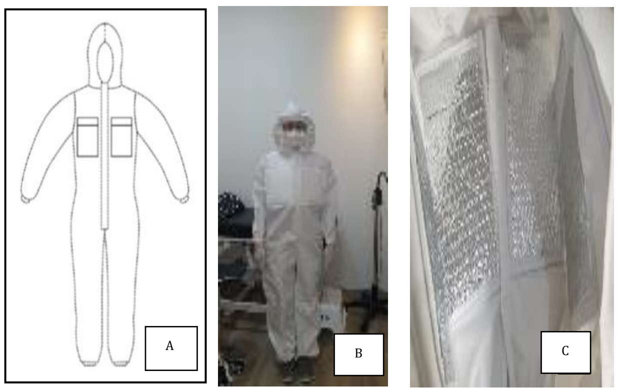
MATERIAL AND METHOD

This study was a retrospective observational one, using a healthcare workers' perspective (i.e., doctor, specialist, dentist, and nurse) and qualitative database within a single population or sample with questionnaires (11 questions) from June 2020 to May 2021 at several health facilities (i.e., hospital and polyclinic) in Jakarta and Bekasi, West Java, Indonesia. This study also analyzed several Laboratory tests of personal protective clothing materials.

Producing a Prototype of Personal Protective Clothing

The methods and stages of technological development in manufacturing personal protective clothing are as follows:

Building a prototype of personal protective clothing; making fabric materials using non-woven milky waterproof polyester fabric coating 100%, Gramasi 0.75 Taslan, and storage bag sample from 2-sided bubble aluminum metalizing foil + PE Bubble thickness: 4 mm, using design for four ice pack pocket and cooling effect. The ice pack type is Unimom with BPA-free and nanosilver plastic packaging as antibacterial & deodorant. It is safe with food-grade standards and harmless in preserving breast milk, food, or cold drinks for +/- 2 hours.



Source: Primary Data, 2020

Figure 1. Personal Protective Equipment Gown Design (A) Perspective Gown Design (B) the Whole Look of Cover-All Type of Protective Clothing, (C) Ice-Pack Inner Design

Laboratory Testing of Personal Protective Clothing Materials

Personal protective clothing was analyzed using three standard tests from the Ministry of Health. First, the use of material morphology was analyzed with Scanning Electron Microscope (SEM) method located in polymer technology laboratory, Agency for the Assessment and Application of Technology, *Badan Pengkajian dan Penerapan Teknologi* (BPPT). Second, a droplet/water repellent test for water resistance was utilized by examining the impact of penetration test results. Third, a hydrostatic pressure test was applied. The fabrics' resistance to water penetration was measured by the standards of the American Association of Textile Chemists and Colorists (AATCC).

Comfort Testing of Personal Protective Clothing

The comfort was tested by a questionnaire consisting of 11 questions regarding suitability and convenience to wear personal protective clothing. This study used a descriptive research method. Fourteen health workers from various professional fields, including general practitioners, specialists, general dentists, specialist dentists, nurses, and midwives, enrolled as participants. These respondents were requested to wear the personal protective clothing with four ice packs of silver nano type divided into 2 ice bags, each on the front (chest), at the right, and left, and 2 ice bags on the back (back) at the right and left, for 2 hours during patients' handling.

RESULTS

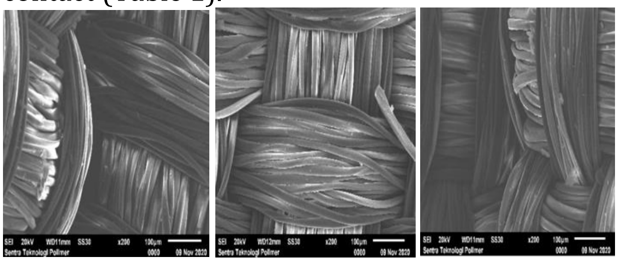
Morphological Analysis Test Results

The prototype test results for personal protective clothing using a Scanning Electron Microscope (SEM) were conducted in the polymer technology laboratory, Agency for the Assessment and Application of Technology (BPPT). This microstructure analysis was expected to observe the structure or pore density of the sample fabric with a magnification of up to 200x. Figure 2 shows the material micrograph with unbroken webbing of the intact polyester yarn of 15-30μm thickness without pores.

Droplet/Water-Repellent Analysis Results

In the droplet analysis, related to the classification of personal protective clothing, parameters based on the WHO standards were involved, including a standardized test of the American Association of Textile Chemists and Colorists (AATCC) and the Association for the Advancement of Medical Instrumentation (AAMI). However, the water-resistance test has two parts: the Impact penetration test (AATCC 42) and the Hydrostatic Pressure test (AATCC 127). The Impact penetration test (AATCC 42) defines how fast and deep the fluid travels to the fabrics and quantifies the impact penetration of water under spray. The Hydrostatic pressure test (AATCC 127) determine the ability of fabric material to resist water penetration under increasing hydrostatic water pressure, while the pre-wash results matched the requirements. Moreover, the second parameter assessed the penetration-resistance level, based on AAMI classification.

The first inspection indicator outcome was dependent on the Acceptable Quality Level (AQL) requirements with spray impact value ≤ 1.0g and hydrostatic pressure ≥ 50 cm H_2O. Meanwhile, the second referred to the classification of exposure risk prevention categorized into first (low), second (moderate), and third (high) levels. Further, the results of this personal protective clothing test were included in the third level (high) classification. According to the AATCC, 42 impact penetration test and hydrostatic pressure test (AATCC 127) results showed that fabrics sample could resist the initial water impact and have hydrostatic resistance from high-pressure water contact (Table 1).



Source: Primary Data, 2020

Figure 2. Morphological Analysis of 100% Milky Waterproof Polyester Coating Material Using a Scanning Electron Microscope (SEM) With 200x Magnification and 100μm Bar Scale Information

Table 1. The Results of Test Parameter Water Repellent Analysis

No	Test Parameter	Result
1	Before washing AATCC 42	Pass
2	Before washing AATCC 127	Pass

Source: Primary Data, 2020

Personal Protective Clothing Comfort Test Results

A total of 14 respondents were included in this survey. These data show the comfort test results using a questionnaire. According to the results of this questionnaire, the average time for wearing personal protective clothing was 2 hours. Most healthcare workers feel wearing PPC was simple or easy-to-use, comfortable, not-hot-to-use, and has no allergy effect including itching, redness, and soreness on their skins (Table 2).

DISCUSSION

Healthcare workers have an increased risk of contamination with COVID-19 due to exposure to disease with COVID-19 patients.[12] Effective use of Personal Protective Equipment (PPE) is a major potential effort in tackling COVID-19 spread, according to WHO. The set comprises personal protective clothing (PPC), eye protection (goggles and face shield), gloves, and masks.[13] Moreover, healthcare facilities are required to provide clinical security guarantees for both medical workers and the public.[14] An important principle of quality health service institutions is the protection of patients, health workers, support personnel, and the surrounding community from disease transmission, particularly, coronavirus. This effort is only realized by implementing effective and efficient disease prevention and control.[15] Also, infection control is highlighted in the 6th and 7th Millennium Developmental Goals (MDGs), including proper cross-infection control, which is needed to prevent infectious diseases during patient care. In 2020, WHO targeted an increase in the number of competent services to recognize and reduce the transmission risk of contagious ailments in dental and oral health services.[3]

The general goal of PPC is to inhibit disease transmission by filtering or mitigating a person from exposure to hazardous substances, including body fluids, harmful microorganisms (bacteria or viruses) and to minimize the risk of cross-infection.[16] PPC is usually made of synthetic fiber, using several types of fabrics with the help of non-woven, weaving, or knitting technologies. Non-woven fabrics are the most valuable for PPC and have a high level of sterility, infection control, and are cheap to manufacture.[17] PPC can be either single-use (disposable), multi-use (reusable), or can be washed after use. Reusable PPC is usually made of 100% cotton, 100% polyester, or with a polyester/cotton blend.[18] This study used personal protective clothing material made of synthetic fiber or non-woven waterproof polyester coating material due to its better liquid barrier properties. The material design in this innovation is a 100% polyester cover-all with possible reuse after washing and sterilization. Non-woven fabrics have a semi-porous layer with selective pores, a non-porous state, as well as hydrophobic properties, which means that they are not wet with liquids, or are water-repellent.

Samples in this innovative protective clothing were laboratory-tested, with hydrophobic properties. However, pathogenic microorganisms, including viruses, tend to instigate disease transmission through exposed skin from direct contact with infected body fluids. Further, the increasing concern of health workers with the exposure to pathogenic microorganisms originating from blood, body fluids, and other contagious sources requires safe and comfortable personal protective equipment.[19] One aspect of PPE is decontamination of clothes (protective clothing), which aims to prevent contamination in certain body regions, commencing from the head and other parts, designed according to the Association for the Advancement of Medical Instrumentation (AAMI) standards and American Association of Textile Chemists and Colorists (AATCC).[20] In 1945, the American Association of Textile Chemists and Colorists (AATCC) is a test for measuring the resistance of garment material to the impact of water penetration and, in 1968, the AATCC used hydrostatic pressure to evaluate fabrics' specimens in a penetration cell.[21,22] This criterion passed with AATCC 42 and 127 laboratory tests, showing that the fabrics sample could resist the initial water impact and demonstrating hydrostatic resistance to high-pressure water contact (Table 1).

Table 2. The Results of the Questionnaire on Respondents After Wearing Personal Protective Clothing for 2 Hours While Handling Patients

Questionnaire about Suitability and Comfort of Personal Protective Equipment (PPE) Form of Person Protective Clothing (PPC)	Statement			
	Strongly Agree	Agree	Less Agree	Disagree
I feel the use of cool PPE in the form of PPC is based on the personal protection requirements of health workers	71.4%	28.6%	-	-
I feel using a cool PPE in the form of PPC tends to increase work productivity while rendering services to patients	64.3%	35.7%	-	-
I feel the use of cool PPE in the form of PPC does not interfere in service delivery	42.9%	57.1%	-	-
I find the use of cool PPE in the form of PPC very easy to use	28.6%	64.3%	7.1%	-
I feel no obstacles in moving my limbs when using the cool PPE in the form of hazmat,	42.9%	50%	7.1%	-
I feel that using a cool PPC appears more comfortable, compared to any regular type	57.1%	42.9%	-	-
I don't feel hot after using cool PPC for more than 2 hours	71.4%	28.6%	-	-
I feel that using the cool PPE has no effects, including itching, redness, and soreness on my skin	64.3%	35.7%	-	-
I feel that the use of a cool PPC doesn't appear light	-	14.3%	64.3%	21.4%
I use cool PPC and headgear comfortably while performing tasks	50%	50%	-	-
Cool PPC stays in sound conditions (doesn't tear easily)	78.6%	21.4%	-	-

Source: Primary Data, 2020

The design of personal protective clothing is expected to meet the regulatory factors of use, protection level, comfort, and cost. Decontamination clothes require a barrier effect capable of avoiding liquid penetration, with high functionality or mobility, comfortable, not easily torn, fitting the body size of health workers, bio-compatible, flammable, and displaying sound maintenance.[23] Further, certain manufacturers of personal protective clothing are encouraged to incorporate safety, reusability, high comfort. The level of comfort is very significant in satisfying the requirements for personal protective clothing, both in terms of use (function) and temperature (not hot).[23] Personal protective equipment (PPE) can potentiate heat stress, which may harm the healthcare workers' performance, comfort, and safety.[24] The temperature in the operating room is usually 15 to 25 °C and humidity 30% to 60%. The temperature of the operating room could increase during the treatment. Additionally, healthcare workers with high-stress situations can release their body heat and discomfort.[25] However, reusable clothing demonstrates higher thickness, compared to the disposable faction, causing unnecessary discomfort as air circulation produces less heat.[19] Therefore, reusable clothes are innovated while creating a feeling of comfort.

This innovative design of personal protective clothing was produced with nano silver-type ice storage bags on 2 fronts and 2 backs. The interior was coated with 2-sided bubble aluminum metalizing foil with 4mm thickness of 4mm, showing excellent capacity to store ice pack, without any wetness. Liquid cooling is a common strategy for the thermal protection of thermal PPCs. Compared to other studies, PPC uses a cooling system called water-containing channels in a liquid cooling garment.[26] This study uses high electrical voltage to accelerate the circulation of dielectric coolant in a stretchable pump. Using this system, the liquid cooling garment could resist temperature rise.[27] According to our study, we want to create not only simple but also low-cost and comfortable PPC. The results of the comfort test using a questionnaire from 14 healthcare workers from various medical fields generally showed that the end product was more comfortable by creating a cool atmosphere (Table 2). Therefore, healthcare workers are expected to be more relaxed and safer.

CONCLUSION AND RECOMMENDATION

This study concludes that the personal protective clothing with ice pack was simple, comfortable, and not hot to use. The recommendation for this study is not to limit personal protective clothing to health services but use it in various types of clothing designs (fire suits, field vests, etc).

ACKNOWLEDGMENTS

We thank the National Research and Innovation Agency (*Badan Riset dan Inovasi Nasional*), Indonesia Endowment Fund for Education (*Lembaga Pengelola Dana Pendidikan*), Universitas Trisakti, healthcare workers at Omni Hospital at Pekayon Bekasi, Kosambi Maternity, and Children Clinic, Agency for the Assessment and Application of Technology (*Badan Pengkajian dan Penerapan Teknologi*), and Qualis Indonesia Company's laboratory, Raissa Embroidery Malang.

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