

Do white coats on polyester fabrics act as a barrier against fluids and bacteria?

Jalecos em têxteis de poliéster agem como barreira contra fluidos e bactérias?
¿Batas médicas de telas de poliéster actúan como barrera contra fluidos y bacterias?

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Abstract

Objective: To evaluate polyester fabrics as physical barrier function against fluids and bacteria.

Methods: This is an in vitro experimental laboratory research carried out in three stages: evaluation of the length of time for the fluid to pass through the fabrics, timed from the beginning of the fluid flow until the formation and fall of the last drop; microbiological determination of the bacterial load in the fluid, after its passage through the fabrics; and analysis of the structural characteristics of the fabrics by scanning in electron microscopy. The data were submitted to normality tests and the Mann–Whitney *U* test, with a significance level of $\alpha=5\%$.

Results: Comparisons of length of time in the first stage between the two types of fabrics used showed a statistical difference ($p<0.001$). Regarding the microbiological evaluation, there was no difference among bacterial loads after the fluid passed through the fabrics, both for *Staphylococcus aureus* ($p=0.056$) and *Pseudomonas aeruginosa* ($p=0.320$). The analysis by scanning electron microscopy showed structural differences between the fabrics, however, there were no bacteria on the fabric surface.

Conclusion: Both polyester fabrics used to make white coats did not work as a physical barrier against fluids and bacteria. Thus, the results allowed us to speculate that the polyester coat when in contact with body fluids may allow contamination of the professional.

Resumo

Objetivo: Avaliar tecidos de poliéster quanto à função de barreira física contra fluidos e bactérias.

Métodos: Trata-se de uma pesquisa experimental laboratorial *in vitro* realizada em três etapas: avaliação do tempo de passagem de fluido através dos tecidos, cronometrado desde o início do escoamento do fluido até a formação e queda da última gota; determinação microbiológica da carga bacteriana presente no fluido, após a sua passagem através dos tecidos; e análise das características estruturais dos tecidos por meio de microscopia eletrônica de varredura. Os dados foram submetidos aos testes de normalidade e ao teste de *U* de Mann–Whitney, com nível de significância de $\alpha=5\%$.

Resultados: as comparações dos tempos obtidos na primeira etapa entre os dois tipos de tecidos utilizados demonstraram diferença estatística ($p<0,001$). Com relação à avaliação microbiológica, não foi observada diferença entre as cargas bacterianas após a passagem do fluido através dos tecidos, tanto para *Staphylococcus aureus* ($p=0,056$) quanto para *Pseudomonas aeruginosa* ($p=0,320$). A análise por microscopia eletrônica de varredura evidenciou diferenças estruturais entre os tecidos, no entanto não foi constatada a presença bacteriana na superfície dos tecidos.

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Conflicts of interest: none to declare.

Conclusão: Ambos os tecidos de poliéster empregados para confecção de jalecos não apresentaram função de barreira física contra fluidos e bactérias. Assim, os resultados nos permitem especular que o jaleco de poliéster ao entrar em contato com fluidos corporais pode possibilitar a contaminação do profissional.

Resumen

Objetivo: Evaluar telas de poliéster con relación a la función de barrera física contra fluidos y bacterias.

Métodos: Se trata de un estudio experimental de laboratorio *in vitro* realizado en tres etapas: evaluación del tiempo de pasaje del fluido a través de las telas, cronometrado desde el inicio del derrame del fluido hasta la formación y caída de la última gota; determinación microbiológica de la carga bacteriana presente en el fluido después del pasaje a través de las telas; y análisis de las características estructurales de las telas mediante microscopio electrónico de barrido. Con los datos obtenidos se realizaron las pruebas de normalidad y la prueba U de Mann-Whitney, con nivel de significación de $\alpha=5\%$.

Resultados: La comparación de los tiempos obtenidos en la primera etapa entre los dos tipos de telas utilizados demostró diferencia estadística ($p<0,001$). Respecto a la evaluación microbiológica, no se observó diferencia entre las cargas bacterianas después del pasaje del fluido a través de las telas, tanto de *Staphylococcus aureus* ($p=0,056$) como de *Pseudomonas aeruginosa* ($p=0,320$). El análisis mediante microscopio electrónico de barrido constató diferencias estructurales entre las telas; sin embargo, no se observó la presencia bacteriana en la superficie de las telas.

Conclusión: Las dos telas de poliéster empleadas para la confección de batas médicas no presentan función de barrera física contra fluidos y bacterias. De esta forma, los resultados nos permiten suponer que la bata médica de poliéster, al entrar en contacto con fluidos corporales, puede posibilitar la contaminación del profesional.

Introduction

Health professionals are constantly exposed to various risks (biological, physical, chemical, ergonomic and mechanical) during their work day. Some activities such as body hygiene (bed bath or sprinkling with assistance); dressing; gauge; intravenous punctures and drug therapies; as well as maintaining a biologically safe environment, by cleaning the concurrent and terminal units, can expose these professionals to direct or indirect contact with skin lesions, mucous membranes, body fluids, surfaces and fomites.⁽¹⁻³⁾ Thus, actions aimed at prevention, minimization or elimination of risks are necessary to ensure biosafety: control of microbial contamination of professionals.⁽⁴⁾

In this context, the use of personal protective equipment (PPE) is an important ally, and choosing it will depend on the exposure conditions (contact with the face, hands or body), type (fluids, droplets or aerosols), duration and amount of body fluid.⁽⁵⁾

Among the PPEs, white coats stand out, since they are widely used as a protective barrier by health professionals in exposure to body fluids and biological agents.

However, although there are recommendations by the Center for Disease Control and Prevention (CDC) and the National Health Surveillance Agency (ANVISA) regarding the safe use of the coat during direct health care for patients^(6,7) In line with the World Health Organization (WHO) Patient Safety

policies,^(8,9) it is known that white coats fabrics in contact with certain areas of the human body (chest, forearm, abdomen) are subject to greater pressure and fiber stress, resulting in greater wear and, consequently, greater permeability in these areas.⁽¹⁰⁾

The literature shows conclusive evidence to the fact that, although the contamination of coats is obvious, there are still doubts regarding the permanence time of the viable and feasible microbial load for cross-transmission.⁽¹¹⁻¹³⁾ Thus, we can say that scientific evidence regarding the reduction of the risk of contamination related to the type of fabric, still remains without a definitive answer.^(13,14)

Still, questions about microbiological conditions after and/or during the use of coats, as well as about their effectiveness in individual protection, have emerged, linking their importance to the identification of the health professional, instead of associating them with minimization the occupational risk inherent in the care practice of these professionals who use the white coat overlaid on their uniform or private clothes.⁽¹⁴⁻¹⁶⁾

For this purpose, this study aimed to evaluate different types of polyester fabrics in terms of the physical barrier function against fluids and bacteria.

Methods

This is an *in vitro* experimental laboratory research carried out in three stages: evaluation of the time

of fluid passing through the fabrics; microbiological determination of the bacterial load in the fluid after its passage through the fabrics; and analysis of the structural characteristics of the fabrics by scanning electron microscopy (SEM). Two types of fabrics were made with 100% polyester, oxford (150g/m²) and microfiber (173g/m²), with a pattern like canvas and twill were cut into fragments of 6cm², and used for the development of the experiments, respectively. In addition, the culture mode use was Brain Heart Infusion - BHI (BD Difco, Sparks, MD, United States of America) was used as a fluid.

Stage 1 – Evaluation of the time of fluid passing through the fabrics

Experimental groups were created based on a random sample selection of the following variables: type of fabric (oxford or microfiber), clean or clean and ironed fabrics, and autoclaved or non-autoclaved fabrics. The fabric samples were fixed with the support of metal clamps to the ends of polyvinyl chloride (PVC ¾) pipes, 10cm long, forming sets, which were attached to a wooden support developed by the authors according to the selected experimental group.⁽¹⁷⁾ Each experimental group consisted of 30 samples, and totaled 240 fabric samples. For each sample, already fixed to the support, 5mL of BHI was aspirated with the help of a 20mL syringe and then the plunger of the syringe was removed so that the fluid would drain by gravity into the lumen of the PVC pipe. The passage length of time of the fluid through the fabrics were timed and recorded in seconds from the beginning of the fluid flow in the syringe until the formation and fall of its last drop through the fabric. It should be noted that the action of gravity eliminates biases resulting from the force exerted by the researcher on the syringe plunger, and that because it is an observational assessment, a single researcher was responsible for timing the times.

Stage 2 – Microbiological determination of the bacterial load in the fluid

The microbiological experiments developed during the study were carried out in Class II Biological Safety Cabin type A1 (VECO, Campinas, SP,

Brazil) following the basic principles of asepsis and biosafety. The methodology used was similar to that described in stage 1, referring to the evaluation of the passage length of time of the fluid through the fabrics, differing in terms of sample preparation and the variables involved (type and bacterial load). Standard bacterial strains of *Staphylococcus aureus* (ATCC 25923) and *Pseudomonas aeruginosa* (ATCC 27853) were selected due to their clinical importance. From the recent seeding (incubation at 37°C for 24 hours) of each bacterium, the standardization of the inocula at 10⁸UFC/mL in a spectrophotometer - model 22PC (Spectrumlab, China) was performed, with absorbance readings between 0.080 and 0.100 and length 625nm waveform. When preparing the samples, in order to minimize the risk of external contamination, the ends of the PVC pipes opposite the fabrics were protected with aluminum foil. Subsequently, the sets were packed in surgical grade paper and subjected to an autoclave sterilization process (Phoenix, Araraquara, SP, Brazil) at 121°C for 20 minutes. A total of 60 samples were used in the experiment: oxford/*Staphylococcus aureus* (n=15); oxford/*Pseudomonas aeruginosa* (n=15); microfiber/*Staphylococcus aureus* (n=15) and microfiber/*Pseudomonas aeruginosa* (n=15). Each set was fixed to the wooden support and the aluminum foil was removed aseptically to expose the lumen of the PVC pipe. In a glass flask with 60mL of BHI, 1% of the standardized bacterial inoculum was added. Then, a volume of 5mL of the content in the bottle was aspirated into a 20mL syringe. With the syringe positioned in the lumen of the PVC pipe, and the plunger of the syringe was removed so that the fluid would flow by gravity. The product of passing the fluid through each sample was recovered in a sterile flask and a 50µL aliquot of the recovered fluid was subjected to serial decimal dilution (10⁻¹ to 10⁻⁵), with fresh and diluted samples being sown on the surface of Petri dishes (15x90mm) with selective culture media for *S. aureus* - Mannitol Salt Agar (BD Difco, Sparks, MD, United States of America) and for *P. aeruginosa* - Cetrinide Agar (BD Difco, Sparks, MD, United States of America). After the incubation period of the samples at 37°C for 24 hours, the bacterial load

was determined and expressed in colony-forming units per milliliter of fluid (UFC/mL).

Stage 3 – Analysis of the structural characteristics of the fabrics by scanning electron microscopy (SEM)

Fabric fragments of about 1cm² for each microbiological experimental group, as well as samples of control fabrics, with the passage of the fluid without bacterial inoculum, were cut out for analysis of structural characteristics and/or bacterial retention by SEM. The fragments were individually immersed in 2.5% glutaraldehyde for at least 12 hours to fix biological material and dehydrated in a series of alcohols (15%, 30%, 50%, 70%, 95% and 100%) for 15 minutes at each concentration. Once dehydrated, the samples were fixed in stubs, submitted to three evaporation stages with carbon (electric current: 2.0A), metallized with gold under 0.1mbar pressure for 180 seconds and, finally, analyzed in a scanning electron microscope Zeiss EVO 50 (low vacuum mode). The data obtained in the first two stages were tabulated and properly coded in an electronic spreadsheet by double typing. Then, the data were subjected to Kolmogorov–Smirnov and Shapiro–Wilk normality tests. We used statistical analysis to assess the difference between the experimental groups based on the variables: type of fabric (oxford or microfiber), clean or clean and ironed fabrics, and autoclaved or non-autoclaved fabrics (stage 1), and types of fabrics and bacteria (stage 2). The median values of fluid passage time and bacterial load were submitted to the Mann–Whitney *U* test for independent samples. For data analysis, we used the SPSS version 24 software with a significance level of $\alpha=5\%$.

Results

Comparisons of the median values of fluid passage times between oxford and microfiber fabrics samples showed a statistical difference ($p<0.001$), with oxford fabrics samples, in general, showing lower values of time of fluid passing through the microfiber samples.

However, comparisons between experimental groups related to each type of fabric indicated that most variables did not influence the length of time that the fluid passed through the fabrics ($p>0.05$), except for the clean and ironed microfiber fabrics, which showed statistical difference ($p=0.008$) when comparing the autoclaved and non-autoclaved variables.

Regarding the evaluation of the fabric as a physical bacterial barrier, the results of the bacterial loads median obtained after the passage of the fluid intentionally contaminated through the oxford and microfiber fabrics did not show statistical difference for both *Staphylococcus aureus* ($p=0.056$) and *Pseudomonas aeruginosa* ($p=0.320$).

Electromicrographs obtained by SEM allowed to identify structural differences between oxford and microfiber fabrics (100x) and showed the presence of macropores (350X), especially in the samples of oxford fabrics (Figure 1).

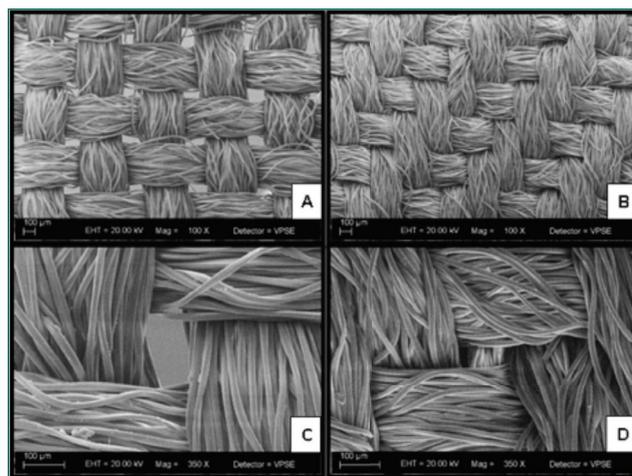


Figure 1. Topographic electromicrographs of oxford and microfiber fabrics. (A) panoramic view of the oxford fabric; (B) panoramic view of the microfiber fabric; (C) macropore in the region of intersection of the oxford fabric threads; (D) region of intersection of microfiber fabric threads

Structures with irregular shapes and crystals were identified on the surface of the threads of both fabrics, however, there was no *S. aureus* (Figure 2) and *P. aeruginosa* (Figure 3) in the investigated fields of the analyzed oxford and microfiber samples.

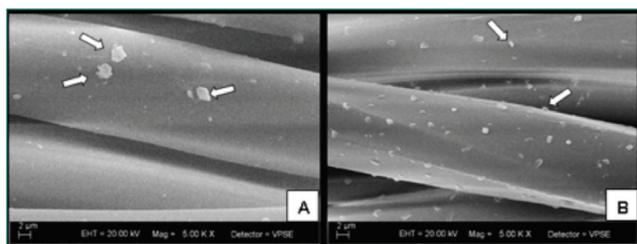


Figure 2. Electromicrographs (5000x) of the fabrics after passing the fluid plus the bacterial inoculum (*Staphylococcus aureus*). (A) irregular structures on the surface of the oxford fabric thread; (B) irregular structures on the surface of the microfiber fabric thread

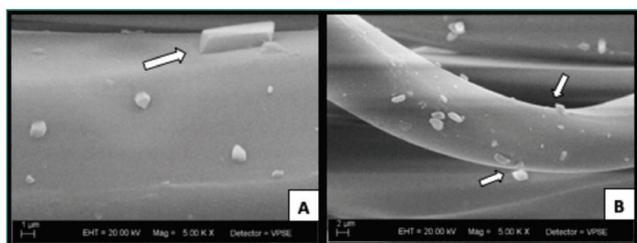


Figure 3. Electromicrographs (5000x) of the fabrics after passing the fluid plus the bacterial inoculum (*Pseudomonas aeruginosa*). (A) crystal on the surface of the oxford fabric thread; (B) crystals on the surface of the microfiber fabric thread

Discussion

The use of textiles in health services represents research topics in terms of contamination and microbial transmission, even microorganisms resistant to antimicrobials. The possibility of spreading this contamination, particularly in hospitals, awakened the industry to this problem, resulting in an increasing production of textiles with antimicrobial agents, such as hospital bed linen and protective clothing.^(18,19)

These new antimicrobial properties can be incorporated into textiles, through the addition of different chemical or physical functional agents in the fibers.⁽²⁰⁾ Thus, metal nanoparticles and oxides are the chemical agents most used to confer antibacterial and antifungal activities.

These fabrics with enhanced functionalities are great interest to healthcare environments, textile and food industries due to their ability to inhibit the formation of biofilms, prevent microbial spread and remove sources of infection.

The white coat is widely used by health professionals in the context of assistance, in order to min-

imize the risk of contamination of the professional and internal clothes by microorganisms during direct or indirect assistance to the patient, since they frequently come into contact, for example, with contaminated and/or moist surfaces, droplets, aerosols and body fluids.⁽²¹⁻²³⁾

Some recommendations are made by ANVISA in line with the WHO and CDC Patient Safety policies, aiming at good practices and the proper use of white coats or aprons.^(6-9,24) However, the literature has identified high loads of white coats contamination, configuring them as possible means of cross-transmission of microorganisms among people, hospital environment and community.^(13,21,25,26)

Considering the problem of the risk of infection resulting from microbial dissemination through white coats, several recommendations were standardized in order to minimize it. According to Law 14.466, of 6/8/2011, the use of PPE, especially white coats, is prohibited outside the work environment.⁽²⁷⁾

Another discussion that arises concerns the name given to the white coat, since according to the provisions of Regulatory Standard 6 (RS6) published by the Ministry of Labor, in its Ordinance 3214, of June 8, 1978, all necessary PPE for professional practice must be made available by the contractor and must necessarily present the certificate of approval (CA), indicating that the equipment has been subjected to analyzes and tests that prove its effectiveness.^(16,28)

Souza (2017) questions in his research the categorization of the white coat as PPE instead of uniform/clothing and infers that the origin of the misunderstanding stems from the use of the term white coat as a synonym for apron in the Portuguese language, under the erroneous semantic interpretation of the terms white coat and apron or gown employed in the English language.⁽¹⁶⁾

Still, scientific studies argue that the white coat is a clothing/uniform and, therefore, performs the function of identifying the professional rather than his/her security. In addition, the white coat would be associated by patients with greater reliability in the professionals involved in health care.^(15,16,29)

Undoubtedly, this topic is complex and generates a series of concerns regarding the use of white

coats as personal protective equipment and encourages reflections in view of the variability of working conditions of health professionals.

In addition, we propose to develop an in vitro experiment regarding the physical barrier exerted by the fabrics when subjected to fluids and bacteria and, consequently, contribute to the understanding of the challenges inherent to occupational exposure in the health area.

It is important to mention that the oxford and microfiber fabrics used in this study are composed of synthetic multifilament threads (100% polyester) whose production process happens in a similar way.^(30,31)

In general, flat fabrics are produced by intertwinning threads that can occur in a simple or complex way. Still, the forms of ligament between the threads provide the fabrics distinct characteristics in terms of physical issues such as flexibility, porosity, sensation to the touch, visual aspect, among others.⁽³⁰⁾

The oxford and microfiber fabrics used in this study showed different structural characteristics, with canvas and twill type ligaments, respectively, as well as the presence of macropores, as evidenced in the electromicrograph shown in figure 1.

Thus, considering that the oxford and microfiber fabrics were made from the same raw material, it is possible to infer that the differences in the times of fluid passing through the fabrics occurred as a result of the structural peculiarities inherent to them.

Another aspect investigated showed that the fabrics used did not prevent the passage of bacteria in the presence of fluid, under the conditions of the experiment, regardless of structural and grammage differences in the fabrics.

The use of white coats by health professionals raises some questions regarding the structure (pattern/weave) of the fabrics, which can facilitate the passage of microorganisms. Furthermore, the hydrophilicity characteristic contributes to its “low degree of efficiency as a microbial barrier - bacterial filtration efficiency of 34%”.⁽³²⁾

Despite of technological advances that make it possible to minimize cross-contamination carried by PPE, it is observed that the market has been

promising, such as the impregnation of dental-medical-hospital supplies and articles, and even fabrics with antimicrobial activity.⁽³³⁻³⁵⁾

It is worth mentioning that the white coats, routinely used by health professionals as PPE, do not have a certificate of approval (CA), nor norms or guidelines that make recommendations as to the type of fabric and grammage that should be used for their manufacture.

Finally, it should be considered that since this is an original methodology, this method is subject to improvement, for example, by verticalizing the position of the fabric. Still, this research has limitations inherent to the experimental model in vitro, such as the use of only one fluid (BHI), two different species of bacteria (*S. aureus* and *P. aeruginosa*) and two types of fabrics (oxford and microfiber) under controlled conditions, making extrapolation to clinical practice difficult.

The relevance of the research directly impacts the practice of healthcare professionals who wear white coats as PPE. Coats can be a potential source of cross-contamination inside and outside the workplace. Still, according to the results of this study, we can infer that the white coat fabrics will not function as a bacterial barrier in the presence of fluids and, therefore, must be immediately replaced as they represent occupational risk.

Conclusion

Polyester textiles for making white coats did not function as a physical barrier against fluids and bacteria. The images obtained by scanning electron microscopy (SEM) showed structural differences (macropores) in the oxford fabric, corroborating the shorter fluid passage length of time.

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Collaborations

We, Felipe Lazarini Bim, Lucas Lazarini Bim, Rachel Maciel Monteiro, Marinila Buzanelo Machado, André Pereira dos Santos, Denise de Andrade and Evandro Watanabe, authors of the manuscript “Do white coats in polyester textiles act as a barrier against fluids and bacteria?”, declare that our contribution was to design and plan the research project; data collection and/or analysis and interpretation; writing of the manuscript; revision of the manuscript.

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