

Flammability Assessment of Multi-Layered Fabrics

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Abstract

Fabric flammability is influenced by factors such as the composition of the fibre material, the manufacturing process and additional chemical treatments that are applied. These variables make it difficult to predict the nature and intensity of a clothing fire and the risk of injury associated with flame exposure. The severity of an injury will depend on the duration of the exposure and the temperature of the flames. This investigation aimed to identify the flaming characteristics of multi-layered fabric samples, which have not been reported extensively in the literature. Ninety fabric samples were used in this study, including cotton, wool, polyester, nylon and silk. The tests were conducted inside a controlled laboratory environment. The results revealed that fabric flame temperatures and burn times for wool, polyester, nylon and silk decreased significantly with adding one and two fabric layers. This appears to represent a “protective factor” against burn injury. However, the Cotton samples exhibited the opposite. The maximum flame temperature and combustion times were increased when additional layers were applied. Therefore, it is necessary to perform flammability tests that include multiple layers of fabric material when assessing the potential for fire injury in clothing.

Keywords: Clothing fire; fabric layers; injury potential; protective factor

1 Background

Clothing fires represent a significant public health challenge globally. Thousands of injuries, including many deaths, occur each year because of burning garments. Approximately two million persons experience clothing burn injuries every year, and more than 100 000 persons require hospitalization [1,2]. Most fabric materials burn if exposed to flames long enough. However, the fibre content, construction, fabric weight and finish will influence the combustion characteristics where the same fibre used in a different fabric can burn at a different rate [3,4]. In addition, the number of fabric layers can significantly influence the overall flammability of a garment [5]. However, the quantitative impact fabric layers can have on garment fires has not been reported extensively in the scientific literature. This study aimed to quantify the influence of two and

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three layers of fabric on the combustion time and maximum flame temperatures associated with the different fabric types.

The degree of risk of injury posed by a clothing fire can also depend on the environment in which the clothing is worn [6]. Design features can influence the flaming effects. Long and loose-fitting garments are generally at greater risk of combustion than closely-fitting garments [7]. Standards related to fabric flammability have been developed by organisations such as the International Organization for Standardization (ISO), the American Society for Testing and Materials (ASTM) and the National Fire Protection Association (NFPA). Examples of standards that address minimum performance requirements include firefighter protective clothing [8, 9] and clothing used by industrial workers [10, 11]. Some standards address fabric flame spread [12, 13] and clothing for extreme occupational exposures [14, 15].

The severity of tissue damage from exposure to a fabric fire is generally related to the total heat transferred from the flames to the skin and the overall duration of the combustion event [16–19]. The risk of injury, therefore, can be estimated by determining the duration of the flaming cycle and by assessing the maximum flame temperatures. While fire exposure guidelines apply complex thermodynamic descriptors, these guidelines primarily apply to protective clothing used for high-risk occupational settings. However, the flammability ratings of commercially available clothing worn by children and adults are not readily available to the public. A simplified method for communicating the flammability characteristics of multi-layered fabrics, i.e., likelihood of injury, was undertaken to support public health professionals in describing, in general terms, the risk potential for injury when commonly used clothing materials catch on fire.

2 Methods and Procedures

2.1 Fabric Types

Five different types of fabric material were evaluated, including samples of 100% cotton, 100% wool, 100% polyester, 100% nylon and 100% silk. All samples evaluated were 5 cm in width and 20 cm in length. The average weight of each cotton sample was 1.368 7 g, 1.124 1 g, for the nylon sample, 2.205 6 g for the wool sample, 2.707 1 g for the polyester sample, and 0.790 1 g for the silk sample. A total of 90 fabric samples were used in this study.

2.2 Fabric Layers

Each fabric type was evaluated for a one-layer, a two-layer and a three-layer configuration. Every test sequence was repeated three times, and the data was averaged. All fabric samples included staples that merged the samples with each other. The location of the staples on the fabric samples is shown in Figure 1.

2.3 Instrumentation

Flammability tests were carried out inside a laboratory fume hood, which provided appropriate exhaust of the smoke and offered shielding against extraneous airflow. Laboratory air temperature