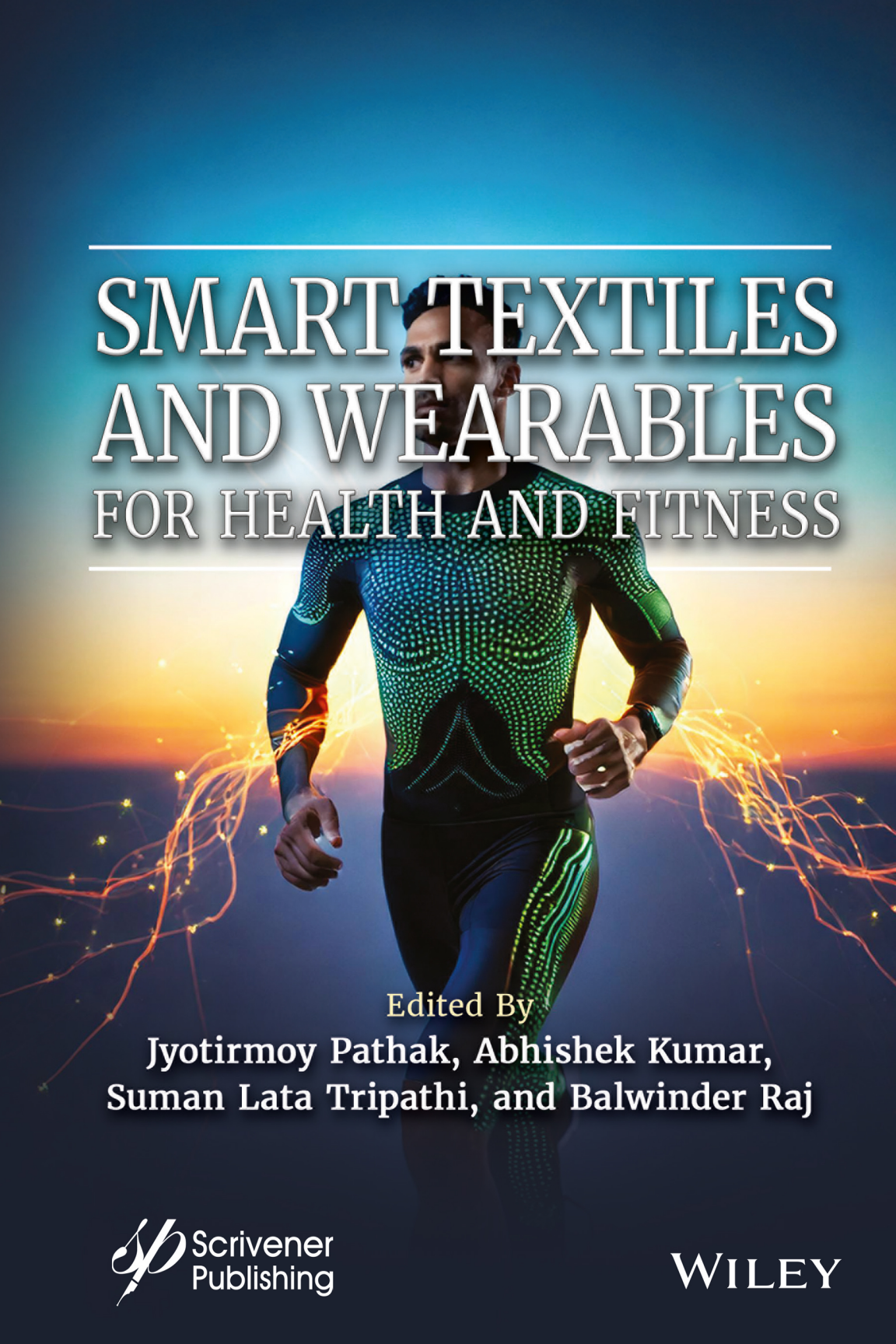
SMART TEXTILES AND WEARABLES FOR HEALTH AND FITNESS



Edited By
Jyotirmoy Pathak, Abhishek Kumar,
Suman Lata Tripathi, and Balwinder Raj

Scrivener Publishing

WILEY

Smart Textiles and Wearables for Health and Fitness

Scrivener Publishing
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

Publishers at Scrivener
Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

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This edition first published 2025 by John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA and Scrivener Publishing LLC, 100 Cummings Center, Suite 541J, Beverly, MA 01915, USA
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Library of Congress Cataloging-in-Publication Data

ISBN 9781394302949

Front cover images supplied by Adobe Firefly
Cover design by Russell Richardson

Set in size of 11pt and Minion Pro by Manila Typesetting Company, Makati, Philippines

Printed in the USA

10 9 8 7 6 5 4 3 2 1

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Preface

Textiles and technology have combined to create a breakthrough in the health and fitness sectors. Wearables and smart textiles, which can dramatically change how we manage, monitor, and improve our health and well-being, are explored. The book *Smart Textiles and Wearables for Health and Fitness* examines the development, application, and future of these innovative technologies within their intricate domain. The book starts with a historical overview outlining the development and beginnings of wearables and smart textiles. We discussed in depth about their specific uses in healthcare, highlighting how they can help manage diseases, track vital signs, and promote overall health. A significant advancement in wearable technology is the integration of AI and machine learning enables predictive analytics and personalized health insights.

The book also examines topics like flexible sensors, bio-integrated textiles, and smart wound protectors. These innovations have the potential to significantly alter patient care procedures. Wearables are transforming sports and fitness by refining protocols for injury prevention, performance assessments, and end-recovery methods. The book additionally incorporates nontraditional areas like the use of smart fabrics in art creation as well as data envelopment analysis to assess hospital efficiency. Each part presents a unique perspective establishing the array of uses for wearables across different fields. It seems that wearable technology has a promising future with ongoing developments poised to introduce new applications. The potential is enormous and game-changing, ranging from sophisticated emotional classification utilizing EEG data to non-invasive blood sugar testing. To move toward healthier, more connected futures, we hope that our investigation will encourage future innovation and collaboration in this interesting sector.

1

History of Smart Textiles and Wearables

K. Jothimani*, S. Hemalatha, S. Selvaraj and R. Thangarajan

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Abstract

Smart textiles and wearables represent a fusion of technology with traditional textiles, revolutionizing various industries such as healthcare, fashion, sports, and the military. This paper provides an abstract of the historical evolution of smart textiles and wearables, tracing their development from early concepts to contemporary innovations. The journey begins with the earliest instances of incorporating technology into textiles. The Industrial Revolution marked a significant shift with the introduction of mechanized textile production, setting the stage for further advancements. The mid-20th century witnessed the emergence of functional textiles, including flame-resistant fabrics and moisture-wicking materials, laying the groundwork for future smart textile applications. The late 20th and early 21st centuries witnessed rapid progress driven by advancements in materials science, nanotechnology, and electronics miniaturization. The development of conductive fabrics, flexible electronics, and sensors led to the creation of interactive textiles capable of sensing, reacting, and adapting to environmental stimuli. Wearable technologies evolved from bulky prototypes to sleek, integrated systems, enhancing user experience and functionality. Key milestones such as the introduction of wearable fitness trackers, smart clothing for medical monitoring, and fashion-tech collaborations are highlighted. Innovations in energy harvesting and power management have also contributed to the autonomy and longevity of smart textiles and wearables, reducing dependence on external power sources. Moreover, advancements in data analytics, artificial intelligence, and connectivity technologies like Internet of Things have further expanded the capabilities of smart textiles and wearables. They now play pivotal roles in health monitoring, performance enhancement, augmented reality experiences, and even environmental sensing. The paper concludes with a discussion of current trends and

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Jyotirmoy Pathak, Abhishek Kumar, Suman Lata Tripathi and Balwinder Raj (eds.) Smart Textiles and Wearables for Health and Fitness, (1–26) © 2025 Scrivener Publishing LLC

prospects, emphasizing the potential of smart textiles and wearables to continue transforming industries and enriching human lives. Challenges such as sustainability, scalability, and privacy concerns are also addressed, highlighting areas for further research and innovation in this dynamic field.

***Keywords*:** Smart textiles, wearable technologies, textile innovation, historical development, materials science, flexible electronics, sensors

1.1 Introduction

Smart textiles and wearables refer to innovative materials and clothing items that incorporate advanced technologies to enhance functionality and provide additional features beyond traditional textiles and garments. Smart textiles are fabrics that have been engineered to have capabilities beyond those of conventional textiles, often integrating electronic components or other advanced materials [1]. These textiles can sense and respond to environmental stimuli or user inputs such as changes in temperature, motion, or biometric data. Examples include fabrics with embedded sensors for monitoring vital signs, textile-based displays for information visualization, or fabrics with integrated heating elements for temperature regulation. Wearables, on the other hand, are electronic devices or accessories that can be worn on the body, often in the form of clothing, accessories, or sensors, and are designed to collect data, provide feedback, or perform specific functions. Wearable devices may include fitness trackers, smartwatches, augmented reality (AR) glasses, or even implantable devices [2]. They can range from simple devices that track physical activity to complex systems that monitor health metrics, enable communication, or augment human capabilities. Together, smart textiles and wearables represent the intersection of fashion, technology, and functionality, offering new opportunities for personalized, interactive, and adaptive experiences in various domains including healthcare, sports, fashion, and entertainment. Some of the key importance and applications of smart textiles and wearables in different industries include healthcare, fitness and sports, fashion and apparel, military and defense, industrial manufacturing, entertainment, and media.

1.2 Early Concepts and Historical Background

The concept of smart textiles and wearables has its roots in early human history, where people used natural materials like animal skins and plant

fibers for clothing and protection. However, the integration of technology into textiles and garments is a more recent development. Early Innovations: While textiles have been used for millennia, the incorporation of technology into fabrics began to emerge in the late 19th and early 20th centuries. Early innovations included the development of synthetic fibers like nylon and polyester, which offered strength, durability, and elasticity. Applications include military, space exploration, and medical textiles.

1.2.1 Incorporation of Technology in Textiles: Ancient Practices

While the integration of technology into textiles may seem like a recent development, there are historical precedents that demonstrate early forms of incorporating technology into fabric production and design. Here are some examples of ancient practices that involved the incorporation of technology in textiles: The first one is weaving techniques: Weaving, one of the oldest textile production techniques, involves the interlacing of threads or fibers to create fabric. The Egyptians, Mesopotamians, and Chinese developed sophisticated weaving technologies, including looms and spinning wheels, to produce textiles for clothing, household items, and trade. These early weaving techniques can be considered a form of technology that enabled the mass production of textiles. The second one is dyeing and printing: Ancient cultures developed various methods for dyeing and printing textiles to add color, patterns, and decorative motifs to fabrics. Techniques of batik, tie-dyeing, and block printing involved intricate processes and specialized tools to apply dyes and pigments onto textiles. These early methods of textile decoration can be seen as a form of technology that enhanced the aesthetic appeal and value of fabrics. The third one is embroidery and embellishment: Embroidery is another ancient textile technique that involves stitching decorative designs onto fabric using needle and thread. Ancient civilizations across the world, including the Greeks, Romans, Persians, and Chinese, practiced embroidery to embellish clothing, accessories, and ceremonial textiles. Embroidery required skillful craftsmanship and specialized tools, demonstrating an early form of technology in textile ornamentation. Finally, textile reinforcement: In ancient times, textiles were often used for practical purposes beyond clothing, such as for construction, transportation, and protection. Techniques like felting, quilting, and padding were employed to create textiles with enhanced strength, durability, and insulation properties. For example, ancient nomadic cultures used felted wool to construct portable tents and

clothing for harsh environments, showcasing the use of textiles as a form of technology for shelter and insulation.

Incorporation Technologies Used:

- Sensors
- Actuators
- Conductive fibers and yarns
- Power supply and storage
- Integrated batteries or energy-harvesting systems
- Microcontrollers and processors

1.2.2 Industrial Revolution and Textile Mechanization

The Industrial Revolution, which began in the late 18th century in Britain and later spread to other parts of the world, had a profound impact on textile production through mechanization and the development of factory systems. Here is an overview of how the Industrial Revolution transformed the textile industry. Mechanization of textile production before the Industrial Revolution, textile production was primarily done by hand using traditional methods such as spinning wheels and hand looms. However, during the late 18th and early 19th centuries, significant advancements were made in textile machinery, leading to the mechanization of various stages of production. The invention of textile machinery that is one of the key inventions of the Industrial Revolution was the spinning jenny, developed by James Hargreaves in 1764 [3]. The spinning jenny allowed for multiple spindles to spin yarn, simultaneously increasing the productivity of spinning and reducing the labor required. This was followed by the invention of the spinning mule by Samuel Crompton in 1779, which combined features of the spinning jenny and the water frame, further improving the efficiency of yarn production. The next introduction of power looms was the development of power looms, which revolutionized the weaving process by automating the weaving of cloth. Power looms used steam power or water power to operate, enabling the mass production of textiles on a much larger scale than was possible with hand looms. The next one is the factory system mechanization of textile production that led to the establishment of large-scale textile factories where machines were powered by steam engines or waterwheels. The adoption of the factory system centralized production in urban areas, leading to the growth of industrial cities'

economic consequences [4]. While it increased the efficiency and output of textile manufacturing, it also led to the displacement of skilled hand workers and the exploitation of labor in factories. The working conditions in textile mills were often harsh, with long hours, low wages, and poor living conditions for workers, especially women and children [5].

1.2.3 Emergence of Functional Textiles

The emergence of functional textiles represents a significant development in the textile industry, where fabrics are engineered to possess specific properties or functionalities beyond traditional textiles. Here is an overview of the emergence of functional textiles: Technological advancements are rapid advancements in materials science, nanotechnology, and textile engineering that enabled the development of functional textiles with enhanced properties and performance characteristics [6]. These advancements have allowed researchers and manufacturers to manipulate the structure and composition of textiles at the molecular level to achieve desired functionalities. Demand for performance textiles: The increasing demand for textiles with enhanced performance properties has driven the development of functional textiles. Sports and outdoor apparel, healthcare, automotive, and protective clothing have specific requirements for textiles that offer moisture-wicking, thermal insulation, UV protection, antimicrobial properties, and durability properties. Innovative materials are the development of new and innovative materials that have played a crucial role in the emergence of functional textiles. Synthetic fibers, engineered polymers, and advanced coatings are among the materials used to create functional textiles with specialized properties [7]. For example, moisture-wicking fabrics are often made from synthetic fibers like polyester or nylon, which have hydrophobic properties that repel moisture.

Figure 1.1 shows that future trends are the future of functional textiles that are likely to be driven by advancements in wearable technology, smart materials, and sustainable manufacturing processes. Self-healing fabrics, energy-harvesting textiles, and biodegradable fibers hold promise for the development of next-generation functional textiles that offer new levels of performance, functionality, and sustainability. Overall, the emergence of functional textiles represents a convergence of technology, innovation, and design, offering new opportunities for creating textiles with enhanced properties and functionalities to meet the diverse needs of modern society.

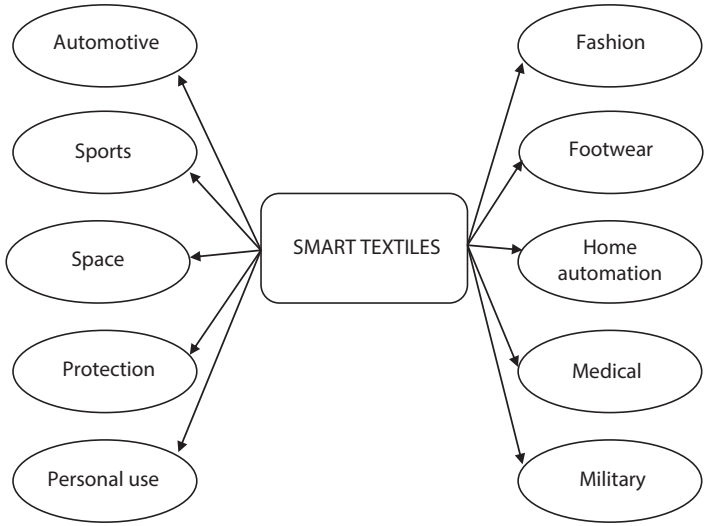

Figure 1.1 Smart textiles applications.

1.3 Advancements in Materials and Technologies

Advancements in materials and technologies have played a crucial role in shaping the development of various industries and applications, including textiles. Here are some key advancements in materials and technologies that have a significant impact on the textile industry.

A. Nanotechnology: It involves the manipulation of materials at the nanoscale (one billionth of a meter) to achieve desired properties and functionalities. In textiles, nanotechnology has been used to develop fabrics with enhanced properties such as resistance, water repellency, antimicrobial activity, and UV protection [8]. Nanoparticles and nanostructures can be incorporated into textiles to impart these properties without compromising the fabric's comfort or breathability.

B. Smart Materials: Smart materials, also known as responsive materials or intelligent materials, are materials that can respond to external stimuli such as temperature, light, or mechanical stress by changing their properties. In textiles, smart materials are used to create fabrics with adaptive properties such as shape memory textiles that can revert to their original shape after being deformed or thermochromic textiles that change color in response to temperature changes. These materials have applications in areas such as healthcare, fashion, and sports apparel.