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The Impact of Technical Textiles on Health and Wellbeing Current Developments and Future Possibilities

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Abstract

he impacts of technical textiles upon society have been influential and have fundamentally impacted upon the structure of everyday human life. As populations continue to age, patient expectations for implant performance will continue to rise. The potential for high performing bio-medical materials is being realized and will continue to advance the evolution towards more fibre based approaches to device development that will perform more effectively and comfortably both outside and inside the human body. Medical textile breakthroughs have provided a broad array of implantable devices including vascular grafts, surgical mesh, heart valve components, orthopaedic sutures and fabric scaffolds designed to aid tissue repair. Technical textiles have the potential to perform better, last longer and increase comfort in the body as well as alleviating concerns around more traditional implanted materials such as metal. Although minimal invasive approaches to cardiovascular and orthopaedic procedures can be promoted with the use of technical textiles, they can be used in a more innovative way than simply repairing or replacing damaged tissue as surgeons can now use their ability to aid regrowth and natural functioning of damaged areas within the body. Global recessions and healthcare cost increases have had a marked global impact on every institution and organisation involved with the delivery of healthcare services and products. The NHS is constantly looking to make savings without compromising quality and this is placing the technical textile industry in a dynamic position to respond to these economic pressures. This paper examines key areas in which innovation in textile technology is promoting health and wellbeing. It considers the commercial and academic context in which these innovations are being developed, examines the main sectors in which these innovations are being directed, and concludes by suggesting which aspects of health and wellbeing are likely to gain the most from the application of technical textiles in the short and long term.

Keywords: Technical textiles; Healthcare; Wound treatment; Textile; Innovation; Biomimicry

Introduction

Textile use in health and wellbeing is nothing new. The Edwin Smith papyrus of 1550 BC provides the first recorded use of cloth bandages, woven metal known as chain mail provided some protection from the 3rd century BC in Europe whilst the Mongols used silk shirts as a barrier to infection in the Asian steppe during the 13th century AD. The acceleration in the possibilities offered by textiles occurred at the turn of the 20th century with the invention of the first synthetic fibres such as nylon, allowing man to select the qualities desired in a textile rather than adapt those offered by natural materials such as wool, cotton and silk.

By the latter half of the 20th century the science of synthetic fabric manufacture had reached such a level of sophistication that a new term was required to differentiate fabrics developed for utilitarian as opposed to aesthetic use: technical textiles. The Textile Institute of Manchester provides the clearest definition of what constitutes a 'technical textile': "Materials and products intended for end-uses other than non-protective clothing, household furnishing, and floor covering, where the fabric or fibrous component is selected principally but not exclusively for its performance and properties as opposed to its aesthetic or decorative characteristics."

Early technical textiles owed their qualities to innovative use of materials, such as polymers. An obvious example with applications for health and wellbeing is Kevlar, a polymer derived fibre invented by Stephanie Kwolek of the Du Pont Corporation in 1964. Five times the tensile strength of steel, Kevlar is used for preventative safety such as the creation of stronger brake pads and cables, and for bulletproof vests. Indeed it has proved so successful in saving lives when used for the latter function that its manufacturer Du Pont has created a Kevlar Survivors' Club.

In the 21st century innovation in technical textile materials continues, indeed it is accelerating. Even more exciting however, are the possibilities offered by new areas of development in synthetic fibres – nanotechnology, fibre coating, non-woven materials, wearable electronics and the increasing use of biomimicry to name the most notable. Reflecting the needs of a world where access to technology continues to be extremely unequal, encouraging research has also been undertaken into how technical textiles can supplement the qualities of relatively cheap and accessible natural fabrics such as wool.

Driving forces behind technical textile innovation

The main areas in which these developments are focussed will be considered in Section 2. Prior to this let us consider the institutions that are driving the rapid pace of technical textile development in the field of health and wellbeing. The remit of these institutions is clearly a major factor in directing research. '

a) Multinationals: American multinationals such as Du Pont can be seen to have led the development of technical textiles during the 20th century. Today they are still actively researching in this field, albeit with an emphasis on evolving existing materials rather than developing

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new ones given the commercial consequences of rendering one of their own products obsolete. A good example of this is the adaptation of Du Pont's Teflon for coating spectacle lenses.

b) Specialist companies: One of the more positive consequences of globalisation is that fabric manufacturers in first world countries have been forced to become technical specialists order to survive international competition. In so doing they have become driving forces of innovation in the technical textile sector, combining a commitment to new ideas with commercial realism. An example is Baltex, the descendent of a 19th century Derbyshire knitting concern. Unable to compete in the standard wool market, Baltex have brought their knitting expertise to development of advanced technical textiles such as their XD Spacer fabrics which provide protection against impact from ballistic threats.

c) Academic institutions: There is a considerable global body of research devoted to technical textiles. This includes first world countries with a traditional of textile manufacture and innovation such as Britain e.g., Manchester's Textile Institute and the University of Bradford and countries which are large scale growers and manufacturers of fabrics today such as India e.g. The Indian Institute of Technology [1]. In broad terms, the former tend towards research into leading edge innovation in technical textiles, whilst the latter can be seen to focus on adaptation of technical textile technology to suit manufacturing and less economically developed areas.

d) Medical bodies: State medical bodes such as Britain's National Health Service and charities such as *Medicin sans Frontiers* provide the bridge between technical textile innovation and the commercial issues associated with their manufacture. Medical Bodies' most significant contribution is their ability to provide projections of current and future health and well-being issues that might be addressed by technical textiles. For instance it was at the instigation of third world medical charities that 'nano meshes' have been developed to filter out bacteria such as gastroenteritis from water supplies.

e) Pressure groups: These organisations draw public, commercial and academic attention to issues that could be addressed through the use of technical textiles. The activities of Age Concern in Britain for example drew attention to the needs of the over-60 age group of the British population with regards to outdoor activities such as walking or jogging as a means of promoting health. The University of Wales now acts as a link between research and commerce in meeting this demand using technical textiles [2].

Main Areas of Technical Textile Innovation

Treatment of wounds

The use of textile bandages to protect wounds from infection is an ancient art. Technical textiles have transformed the bandage from a passive to an active component in healing. An established example is the introduction of alginate fibres derived from seaweed into the part of a dressing in contact with the wound encouraging a 'moist healing' process through the formation of a water soluble gel [3]. More advanced is the use of plasma coatings evolved by the Indian Institute of Technology which are used to affect the surface behaviour of textiles rendering them either hydrophilic (water absorbing) or hydrophobic (water repelling) as the particular nature of the wound requires [4].

Intracorporeal treatment

Non-degradable textiles have a wide variety of applications in internal treatment of the human body. Several current developments have tremendous potential to address specific health concerns. The need for hygienic delivery of non-refrigerated medicine and vaccines in the third world has been addressed both by new technical textiles and by innovative use of natural fabrics. An example of the former is German textile manufacturer Schoeller's iLoad reloadable drug delivery fabric which uses a carrier material to unload medication into the skin when stimulated by moisture, vibration, warmth and perspiration. An instance of the latter is the innovative use of silk by Vaxess Technologies of the USA for the hygienic transport of vaccines. Fibroin, a silk protein is used as a stabilizing agent in the preparation of dessicated vaccines which are rehydrated at point of use [5].

Implants into the body represent an established use of intracorporeal textiles with very broad applications. Age and disease related degenerative conditions as well as the consequences of trauma are all commonly treated by established textiles in the first world – artificial joints are commonly manufactured from polyethylene, artificial corneas from polymethyl methacrylate and artificial skin from a long chain polymer called chitin for example. Existing materials are biocompatible with the human body and thus the problem of the body rejecting the implant has largely been resolved. Deterioration in strength and functionality of the implant owing to the hostile environment of the human body remains an issue however; polyamide commonly used for artificial tendons can lose much of its strength within two years [6]. Clearly investigation into materials for longer lasting implants may provide a significant avenue for technical textile development.

Perhaps the most remarkable current development is the use of microscopic quantities of a nanofibre in the treatment of cancer *within* the bloodstream by researchers at the University of California, Los Angeles (UCLA). One of the main causes of cancer spread through the body are circulating tumour cells (CTCs) which use the bloodstream to establish new tumours. The 'NanoVelcro' chip acts like Velcro, trapping and isolating passing CTCs enabling them to be analysed and individual treatments tailored to the individual [5].

Extracorporeal

Extracorporeal (outside the body) treatments involve the use of mechanical organs, typically for blood dialysis. The innovative use of established textiles has been crucial to the successful deployment of these machines as they form the basis of filters that mimic the actions of membranes within human organs – cellophane for example replicates the function of the kidney in removing waste materials [6]. As it becomes possible to produce artificial versions of a greater variety of bodily organs, technical textiles will undoubtedly have a key role to play in future health.

Monitoring

Traditionally monitoring of the body has been undertaken by gel based wire sensors which are intrusive, unwieldy and difficult to use when a subject is moving. Electronic technical textiles make a fabric based approach to monitoring possible. British company, SmartLife's HealthVest system is an established form of this system currently employed by Manchester Royal Infirmary which uses dry sensors built into a garment to measure heart rate, ECG morphology, respiratory rate and bodily fluid flows. More advanced monitoring fabrics are currently either at the developmental or pre-production stage which essentially offers a wearable electronic hub which can be programmed via wireless technology to monitor a wide variety of bodily functions.

Filtering

Increasing urbanisation is making the global population evermore susceptible to airborne contamination including pollution and germs. Fabric face masks are a standard feature of life in many of the world's more polluted cities, particularly in the Far East. Technical textiles offer more sophisticated means to mitigate the effects of air pollution however, often at source. The use of textile membrane for the contentious issue of CO2 capture for example, is being investigated by Australian research organisation CO2CRC. A porous membrane woven from hollow, solvent filled fibres of polymer diffuses and absorbs CO2 into a treatable liquid Elsewhere an ingenious crowd based solution to air pollution in city centres has been suggested by Catalytic Clothing namely coating the fabric of standard high street clothing with nano-particles of photo catalyst titanium dioxide able to trap airborne particulate which can then be disposed of harmlessly through washing.

The use of nanotechnology in technical textiles can provide beneficial filtering in other areas in addition to air pollution. Carbon nanotubes are now routinely used in water filters in the third world removing viruses such as polio.

Protection

Protection from harm through protective clothing is perhaps the most obvious and widest field of application for technical textiles in the area of health and wellbeing. In general this clothing can be subdivided into the following areas

a) **Contamination:** Industrial and disaster workers have to operate in toxic environments in which bio-hazard suits are needed. Traditional suits made of impermeable materials have been known to cause problems of sweating, misting and heat exhaustion. However the use of laminate materials such as Cloropel, a chlorinated polyethylene allied to positive air pressure within the suits has made 'breathable' [7] bio-hazard protection materials possible. Given the growing demand for environmental clean up operations such as the treatment of radioactive materials in the former Soviet Union for instance, it is likely that increased research will be devoted to developing ever more lightweight and unobtrusive anti-contamination fabrics.

b) Impact: A modern version of traditional armour, impact protection fabrics counter the interrelated risks of explosions, stabbing, shooting and blunt impact. Armed forces and police are the traditional customers, and in view of the threat from Improvised Explosive Devices (IEDs) in modern warfare, there is a particularly pressing need for development in this area.

Body armour made of materials such as Kevlar have now been replaced by second generation ballistic fabrics made of High Performance Polyethylene (HPPE) such as Dyneema which give increased resistance to projectiles such as bullets and shrapnel[3]. Extra panels of ceramic can be added to increase ballistic protection to the point where the wearer is effectively bullet proof. The trade off is twofold – such armour is extremely heavy, a major problem is a fast moving, hot combat environment such as Afghanistan, secondly as a consequence of this weight issue only the head and torso can be protected, hence the high proportion of limb injuries encountered. NATO governments are very aware of this issue and their procurement agencies such as Britain's Integrated Soldier System Executive are driving innovation with substantial investment. Immediate developments include the enhancement of low-tech materials to protect a wider proportion of the body – the British Pelvic Protection System for instance is based on treated silk in the medieval manner which provides lightweight protection against shrapnel. The most promising long term development is to combine high performance polyethylene with a layer of gel that hardens when struck, so-called liquid armour (www.military.com) currently being researched by BAE Systems Ltd and the US Army Research Laboratory which promises to be 50% or less in weight compared to existing systems.

Technical textiles have impact applications, indeed any of the wide variety of professions and activities requiring the use of sharp blades could be rendered safer by its development. In the case of stab protection Dyneema HPPE has just been approved for use in cut resistant gloves by the European Union for abattoir workers and butchers, whilst users of chainsaws utilise technical textiles such as Prolar for leg, hand and groin protection which snag the saw blade. However, these civilian applications tend to be evolutions of military practise rather than drivers of change in their own right.

c) Temperature: Like impact, the requirements of the principle end users are driving rapid innovation in the field of temperature resistant clothing, in this case fire services and the motor racing industry. The same requirements apply to the characteristics of these materials too, namely that they be as light and unrestrictive of movement as possible. Both heat resistance and flame retardance are required in this application. Traditionally man-made fibres have been unsuitable for this application on account of their relatively low melting points (polypropylene melts at 150°C, polyester at 255°C), instead treated natural fibres have found favour – the Royal Navy using hydroxide treated cotton known as Proban whilst foundry workers often use wool treated with hexafluoride known as Zirpro Wool [8]. Treated natural fibres have many advantages such as relative cheapness and breathability. However by their very nature they can only be developed to a certain point, and both the fire service and the motor racing industry have temperature requirements beyond their capabilities.

Du Pont's Nomex is the current material of choice – an Aromatic Polyamide or Aramid able to endure temperatures of up to 400°C without charring. Other technical textiles designed specifically for fire fighter units have even more impressive heat resistant properties such as Rhone-Poulenc's polyamide-imide fibre [8]. In all cases however, although these materials are comparatively lightweight, breathability remains an issue, and it is in this regard that further technical textile development would be most desirable. Laminates may well be the solution -a laminate of synthetic knitwear able to withstand temperatures of over 1000°C for up to 12 seconds was developed by Lamination Technologies Inc of Pennsylvania and is used in the clothing of Andy Green, the driver of the rocket propelled Bloodhound supersonic car. Significantly this laminate traps air pockets using an advanced knitting process which not only improves temperature resistance but also breathability.

d) Ultraviolet: Increased concerns regarding the dangers of ultraviolet light (UV) have led to research into UV filtering in fabrics, particularly beach and swim wear. Cost, comfort, environmental footprint and the demands of fashion are significant factors in these textiles. Given these factors, a naturally derived coating on conventional nylon and polyester is the preferred mode of development, exemplified by Cocona a fibre derived from coconut waste that combines UV and odour absorbent properties [7].

Fitness

The use of technical textiles in filtering harmful sunlight and for monitoring has already been discussed. Beyond these applications the most promising area of development at present is in the area of outdoor pursuits, and in particular making such pursuits more accessible to the West's ageing population. Comfort is the paramount factor here, and in the development of outdoor clothing *biomimicry* is the driving force in research – learning from the ways that natural materials are formed. As the founder of the American Biomimicry Guild Dr Janine

Benyus states, 'Nature has been innovating for 38 billion years, which has given enough time to establish what works and what doesn't [9] An early example of this process is Velcro, whose hooks were inspired by burdock burrs. More recently, Schoeller Textil AG of Switzerland have launched Nanosphere, an 'adsorbent' fabric featuring a rough micro-texture that repels water in the same manner as lotus and nasturtium leaves [9] Schoeller have also addressed the issue of perspiration via biomimicry with its C Change textile which features a membrane which reacts to changing temperature and moisture by opening to allow the escape of heat and water vapour in the manner of pine cones [10].

Investment in the outdoor clothing sector is rising as the market changes, particularly in Europe where the demand for outdoor clothing from the over 50s is rapidly outstripping those of the younger market. Aside from biomimicry, 'smart textiles' are also being developed by the University of Wales – seamless garments incorporating separate panels with different attributes including anti-chafing, insulation and even electronic heating elements. The use of textiles embedded electronics clearly has a great deal to contribute this sector, in addition to clothing and monitoring a wide variety of other applications are also in development such as the solar cell fabric, already available in the form of self-lighting tents, which may well be able to power electrical devfices fin ftThe medfium fterm ffufture [11-15].

Where next?

All the developments in technical textiles explored in this paper have substantial backing and either has or is likely to be manufactured. Which has the greatest potential to affect health and wellbeing depends on context more than technology. In terms of improving the largest number of lives innovative use of affordable natural fibres modified by the addition of technical textiles would seem to offer the greatest potential, as these are accessible to third world relief organisations whose impact is arguably greater than any other health and wellbeing institution –' Vaxess Technologies' desiccated silk protein based vaccine being an excellent example. In terms of the greatest impact in first world countries, nanotechnology fabrics such as Nanovelcro clearly have immense potential in the intracorproeal treatment of common conditions such as cancer and as such may be regarded as the leading aspect [16-20].

Conclusion

Overall however, the most enduring contribution of the global acceleration of technical textile development is not any one innovation but the growth of a pool of expertise. Corporations, charities and academic institutions in the USA, France, Britain, Switzerland, Australia, India and Bangladesh now maintain substantial workforces dedicated to the future development of technical textiles. In so doing they have ensured that mankind's present and future health and wellbeing will be improved by this fascinating field of research and innovation.

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