8

Natural Wool Fabrics in Physiotherapy

Krzysztof Gieremek[1,2] and Wojciech Cieśla[2]
[1]Department of Physiotherapy, Academy of Physical Education in Katowice,
[2]Department of Tourism and Health Promotion, Faculty of Physiotherapy, Katowice School of Economics, Poland

1. Introduction

Prevention of heat loss, thermal insulation and heat treatment play an important role in physiotherapy. For example, peripheral vascular disease associated with metabolic diseases (e.g., diabetes, arteriosclerosis), arthritis, paresis and paralysis of peripheral nerves all require interventions involving heat therapy. Wool products such as garment linings, shoulder-straps, knee pads and lumber pads exert a very positive effect on the above mentioned circulatory disturbances. Moreover, due to its unique physical and chemical properties, knitwear increases the pain threshold and reduces muscle tension; knitwear can be used both before and after exercise to prolong the therapeutic effect. Physiotherapy sessions for little children on wool mattresses also evoke additional sensory impulses thus improving sensorimotor outcomes. Extending the heat effect on the skin resulting from physical procedures such as massage, heat therapy and ultrasounds is regarded as one of the main theraputic advantages. Last but not least, there are also some easily perceivable economic benefits.

In addition, the influence of wool beddings on sleep patterns (associated with thermoisolation and thermoregulation) will be discussed as well as their regenerative effects in patients with somatic disease and depressive disorders.

2. The effect of wool products on human and animal physiology and health

2.1 Physicochemical properties of wool affecting medical value and health benefits of wool fabrics

Wool, a material used to manufacture the fabrics under assessment, is a product of animal origin. The basic type of wool used was merino wool sometimes enriched with camel or kashmir goat hair. Wool fibres of different origins may have varying diameters but still display similar properties.

Wool is primarily made of keratin, an insoluble protein. A wool fibre is composed of three layers, i.e., epidermis (outer layer), tubular cortex (middle layer) and medulla (inner layer).

The medulla makes up the bulk of the fibre and consists of a latticework of spindle cells with air-filled spaces in between; it determines the physicochemical properties of wool. Wool fibres are not straight but more or less bent forming crimps (measured in crimps per inch or crimps per centimetre) of different regularity. The feature distinguishes wool from other fabrics and, to a large extent, determines its uniqueness.

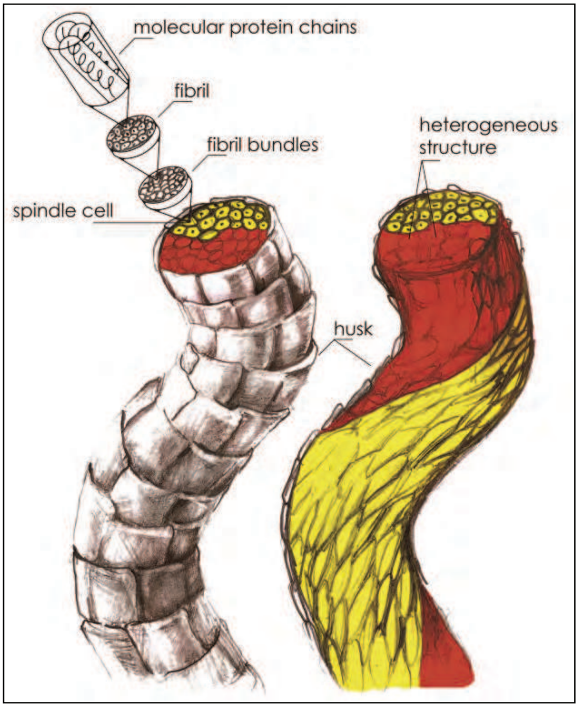


Fig. 1. The structure of a wool fibre.

The properties of wool fabrics that are deemed the most specific and *important for clinical application* are springiness, resilience, **low thermal conductivity**, elasticity and moisture-retaining and thermal insulation properties.

Springiness is the ability of a bent, stretched or compressed object to return to its original form when the acting force is removed.

Resiliency is the property of a material which causes it to resist deformation and return to its original shape when wrinkled or distorted in any way. Natural wool displays these properties; its springiness results from high sulphur content in wool keratin. Both springiness and resiliency are of importance as they prevent wrinkle formation in wool fabrics ensuring a product's durability. Along with the above mentioned wool crimp and scale structure on the fibre, springiness and resiliency cause large air content to be enmeshed in wool; the **amount** of **air** trapped between the yarns and fibers does not change while the fabric is in use. Hence, good thermal insulation and the feeling of warmth. Due to springiness, wool products do not adhere directly to human skin whereby the isolating air layer is increased; the dynamics of mechanical deformation resulting from temperature changes causes sufficient air flow to occur.

*Thermal conductivity***.** Due to its structure and chemical composition of keratin, wool fibre is characterized by low thermal conductivity, a property crucial for a product to be used in heat therapy.

Moisture content. Wool is the most hygroscopic among the so far described fabrics. Its fibres absorb and retain considerable amounts of moisture from the atmosphere distributed in **capillary spaces between fibres.** Through moisture absorption, the fibres prevent rapid temperature changes. Highly **hygroscopic** fibres have a tendency to *maintain temperature*; hence, the unique *insulating properties* of wool. During absorption and condensation of water vapour a considerable amount of heat is produced defined as *absorption heat* (the amount of calories released during absorption of 1g water).

The heat reduces possible effects of low external temperature and facilitates evaporation of the absorbed moisture. Atmospheric moisture is then again absorbed and, through a chemical reaction with wool fibre molecules, helps generate heat to prevent temperature changes. Animal fibres absorb the largest amounts of moisture without physical changes thus displaying considerable insulating properties.

FABRIC TYPE	CAL/G
Wool (64g)	27.00
Argon (viscose fabric)	25.00
Natural silk	19.35
Cotton	11.00
Nylon	7.60

Table 1. Immersion heat generated during the transition from total dryness to the point of complete saturation (Grycewicz & Staniszkis, 1959).

Investigations have been recently carried out on superhydrophilic wool fibres coated with silica nanoparticles which alter surface roughness of the wool fibre and make it more water absorbent. Modified wool has been proven to have excellent properties under different environmental conditions (Chen, 2010).

Elasticity. Water-vapour absorption-desorption cycle influences fibre flexural stiffness in contact with the skin resulting in gentle and nonspecific *mechanical stimulation* of the superficial nerve receptors. Wool products contain lanolin, natural wool wax secreted by the **sebaceous glands** of wool-bearing animals, especially merino sheep. Lanolin and moisture-retaining properties ensure wool elasticity thus preventing fibre rigidity. It is also worth mentioning that lanolin does not allow dirt to penetrate into the fibres which facilitates maintenance process and assures proper hygiene standards for product users.

Thermal insulation. **Woolen garments** outperform other fabrics in maintaining a fairly constant temperature of the human body. The above mentioned structure and properties including fibre crimp, low thermal conductivity, springiness and resiliency increase air entrapment and ensure outstanding thermal insulation. Transferred from dry and warm to wet and cold conditions, wool absorbs atmospheric moisture which reacts with molecules in the wool generating heat (Beuth, 1968; Grycewicz & Staniszkis, 1959; Żyliński, 1958). A wool suit weighing approximately 1.5 kg, when transferred from a dry and warm to wet and cold room will almost immediately produce the amount of heat released by the human body during one hour. Due to **high hygroscopic** susceptibility of fibres, wool garments absorb sweat and prevent overheating in summer.

2.2 Influence of wool fabrics on skin physiology and the efficiency of several body mechanisms

The physicochemical properties of wool fabrics clearly suggest that their primary effects on the human organism would be associated with heat therapy with wool's insulating properties being of crucial importance (Matusiak, 2010). In many patients with peripheral vascular disease, the course of treatment is affected by the equilibrium between the amount of heat generated through metabolic processes and heat release to the ambient atmosphere, commonly referred to as thermal comfort (Sudoł – Szopińska & Chojnacka, 2007). Heat transfer by wool-based fabrics depends, among others, on the product surface, thermal conductivity coefficient of the material used and its effect on the skin. Therefore sufficient knowledge of the influence of different textiles on skin physiology is indispensable.

Wollina et al. (Wollina et al, 2006). believe that all clothing fabrics including wool interact with **skin** functions in a **dynamic pattern**. Thermoregulatory processes mediated by local blood flow, perspiration and sweat evaporation are important elements of the relationship between the skin and textile fibers. Wool products may also influence skin immunity through affecting the major constituents of **skin microflora**. Using laser Doppler flowmetry, Yiming Gan et al. (Yiming et al, 2010). investigated the effects of various natural and artificial fibres on subcutaneous circulation in healthy subjects. They found out that fibre thickness, coarseness, structure and moisture influenced skin temperature and blood flow. Fabric surface characteristics play an important role, especially during the transient heat exchange at the beginning of its contact with the skin. The higher of the moisture level, the longer the duration of the fabric impact on the vascular structures of the skin. The significance of moist heat source on the skin in eliciting blood flow responses in male and female patients was confirmed by the study of Petrofsky et al. (Petrofsky et al, 2009). Moist heat packs caused a significantly higher skin blood flow (about 500% greater) than dry heat. The authors believe that moist heat renders skin thermoreceptors more sensitive due to calcium channels opening in endothelial cells.

Interesting observations have been made by Li Yong from Hong Kong Polytechnic University, who investigated the psychophysical mechanisms of the sensation of temperature and moisture while wearing jumpers made of wool or acrylic fibres (Li, 2005). It has been demonstrated that the perception of warmth follows both Stevens' power law and the Weber-Fechner law[1], and shows positive relationship with skin temperature. Since the perception of comfort is also positively related to skin temperature, wearing wool made the study subjects feel warmer, dryer and more comfortable. Similar conclusions regarding the effects of natural (wool) and artificial (100% acrylic) fabrics on human physiology prior to, during and after physical exercise have been drawn by Ciesielska et al. Each fabric, including those made of natural fibres, influences cardiorespiratory parameters and psychophysical performance (Ciesielska et al, 2009).

[1] Stevens' power law is a proposed relationship between the magnitude of a physical stimulus and its perceived intensity or strength. A hundred years earlier, Weber and Fechner developed a logarithmic law concerning the relationship between the strength of sensation and the size of the sensory stimulus.

Ziemniewska et al. investigated the effect of artificial (polyester) and natural (cellulose fibre) garments on the energy cost of a physical activity demonstrating that garment type influenced the subjects' performance. More hygroscopic fibres were considered more advantageous (Ziemniewska et al, 2010). However, opposite results have also obtained.

When discussing the influence of natural fabric garments on the human organism one should also mention similar research studies done on animals. Shafik - investigated the effect of different types of textile fabrics (polyester, cotton and wool) on dog hair growth (Shafik, 1993). The polyester-patch covered hair grew at a significantly lower rate and density than in the uncovered area. The author concluded that artificial fabrics generated electrostatic potentials which may have inhibited hair growth whereas cotton and wool did not induce such effects. The same researcher also studied the effect of different types of textiles – including wool - on canine reproduction (Shafik, 2008). He measured serum progesterone and electrostatic potentials detected on the skin. Bitches wearing polyester-containing pants showed diminished progesterone levels and ovulation disturbances. Thus, generation of highly disadvantageous electrostatic potentials by artificial fabrics has been confirmed as well as the nonexistence of such a negative impact in the case of wool.

2.3 Thermal and thermoregulatory significance of wool beddings for the improvement of sleep patterns

A large number of users of wool products maintain that wool textiles make a real difference in the comfort and quality of sleep. These effects can be accounted for by thermoregulatory mechanisms. As mentioned before, wool also helps maintain a fairly consistent **body temperature providing thermal comfort. The ability of textiles to ensure thermal comfort under some specific external conditions is referred to** as the Thermal Comfort Index. The parameter is affected by heat conduction, convection, evaporative heat loss and thermal absorption (Matusiak, 2010). Skenderi et al.'s investigations on fabrics made from natural fibre emphasize the capacity of fibrous materials to transfer water vapour and the significance thereof under various climatic conditions (Skanderi, et al, 2009).

Since wool properties counteract temperature changes, it can easily be concluded that wool beddings influence the thermoregulation of the human body during sleep. A number of changes occur during sleep in the thermoregulatory mechanisms of humans and animals. Core temperature rhythms and sleep propensity differ significantly across the day and night. According to Gilbert S. et al. thermoregulatory changes may provide a signal to the brain regions that regulate sleep (Gilbert, et al, 2004). These regions are anatomically and functionally connected with thermoregulatory mechanisms. Considerable relationships have been found between body temperature and sleep/wake rhythms. Patterns of heat exchange alter during sleep; metabolism decreases while heat loss increases resulting in a drop in body temperature (Szymusiak, 2009). Bach V et al. have found that **thermoregulatory** responses **depend** on the **sleep stage** and are affected by ambient temperature. Excessive cold and heat disturb sleep. Moderate pre-sleep body warming enhances SWS (Slow Wave Sleep) and improves sleep continuity. This might be of importance in depressive patients, whose sleep and thermoregulatory rhythms are disturbed (Bach, 2002). Sleeping in cool rooms improves the active stage of sleep, i.e., REM (Rapid Eye Movement), which is, however, related to a decrease in subjective sleep quality. Craig Heller believes that **sleep** and **control** of body **temperature** are intertwined. The comfort of sleep is strongly influenced by body and external temperatures; even slight changes in core temperature have an effect on sleep (Heller, 2005). The association between sleep and thermoregulation play an important role in several disease processes. Tsuzuki (Tsuzuki et al, 2004) investigated the effects of different temperature conditions and humidity on sleep. The subjects dressed in pyjamas and covered with a cotton blanket were assessed in 26°C 50% humidity and 32°C 80% humidity. Melatonin metabolite secretion and the duration of wakefulness were measured. The duration of wakefulness increased significantly at 32/80 while melatonin metabolite secretion in urine was lower at 32/80 than at 26/50, which was consistent with the decrease in sleep efficiency.

The significance of clothing insulation in outdoor sleeping infants during northern winter was emphasized by a team of researchers of the Institute of Health Sciences, University of Oulu, Finland. Inadequate thermal comfort resulting from deficient thermal insulation caused shorter sleep (Tourula et al, 2010).

Recognizing the unique characteristics of wool fabrics, their capacity to counteract temperature changes, insulation properties and an almost immediate impression of warmth in contact with the skin, beneficial effects of wool on thermoregulatory mechanisms and the quality of sleep can be considered certain.

The powerful impact of sleep on health has been well recognized. During deep sleep melatonin levels increase, a hormone which is an antioxidant and suppressant of tumor development through scavenging of free radicals. The incidence of somatic disease in patients suffering from insomnia increases twofold. Insomnia is also among the causes of the epidemics of diabetes, hypertension and lower immune function (Avidan & Zee, 2007).

2.4 Mechanical effects of wool on the skin

Mechanical effects of wool on the skin mostly depend on its properties including resiliency, elasticity, fiber thickness and density. To recap : *resiliency* is the property of a material which causes it to resist deformation and return to its original shape when wrinkled or distorted in any way. *Elasticity*, related to water-vapour absorption-desorption cycle, influences fibre flexural stiffness in contact with the skin (Beuth, 2004). The mechanical effect of wool on the skin also depends on fibre structure. Gualana, a new specialist technology used to manufacture wool fabrics, tumbling/brushing, chemical or gas (ozone) processing, and appropriate blend ratio in blends of cashmere with wool resulting in uniform fibre distribution in knitted fabrics, all these have clearly increased the utility value and beneficial effect of wool fabrics on the human body (Kun et al, 2010). At the same time these fabrics give the illusion of contact with the so called fleece.

A variety of nerve endings enables the skin to detect and differentiate the strength of mechanical stimuli. These include Merkel's touch corpuscles and free nerve endings found in the epidermis and papillary layer of the dermis, Meissner's corpuscles of the papillary layer of the dermis and Pacini's corpuscles scattered in subcutaneous tissues. Hair, rich in nerve endings, acts as a peripheral sensory organ. Even very gentle touch on the hair is transferred to mechanoreceptors in the skin (Bochenek & Reicher, 1989).

Fibre structure and arrangement in wool fabrics stimulate **superficial** sensory nerve endings with different strength. Compared to commonly used products (cardigans, socks, blankets), the amount of wool fibres per 1mm^2 results in far better stimulation of mechanoreceptors in the skin even if the stimulus is of mild or moderate strength. This type of stimulation produces an overly-calming and somniferous **effect; it also has a mild anaesthetic action.** The reflex need for touch on the body part that hurts (laying hands, gentle dubbing) provides evidence for the phenomenon. Stroking techniques of therapeutic massage cause a similar response (Field et al, 1996). Mechanical action of wool fibres on the skin also affects blood supply to this organ. Appropriate roughness of wool fabrics produces – during the use and due to non-irritating friction – some extra heat. This micromassage leads to neurohormone activation, which increases superficial blood flow and rises skin temperature. Thereby, thermal and insulation properties of wool fabrics become further enhanced. Using **thermography** and **thermistor** skin **temperature measurements**, Sefton et al. as well as Gieremek et al. (Sefton et al, 2010; Gieremek et al, 1991) confirmed the effect of therapeutic massage on skin temperature alterations directly associated with changes in peripheral blood flow in the treated areas as well as in adjacent not-massaged areas.

3. Thermal insulation and heat therapy in the treatment of some selected disease entities

Local use of thermal energy triggers several physiological reactions including increases in blood flow, muscle tension release, decrease of joint stiffness, oedema reduction, and, most importantly, pain relief. Impressions of temperature and pain are conveyed to higher centres through the same nerve tracts. General well-being associated with heat therapy is brought about by the release of endorphins and other neurotransmitters modifying the sensation of pain. The complex and interdisciplinary issues of the effect of heat on the skin became the domain of skin biothermomechanics. Thermomechanics also refers to mechanical tension (deformation) of skin collagen, also epidermal collagen. Thus, heat also modifies the sensation of pain via mechanical action (Xu et al, 2008).

The above mentioned effects of heat evoked through the use wool products occur to a greater or lesser degree in the prevention and treatment of several disease entities.

Interesting information concerning the prophylactic action of textiles in the management of decubitus ulcers has been provided by Irzmańska et al. (Irzmańska et al, 2010). The authors report that the factors contributing to the formation of bedsores comprise temperature, humidity and air flow. Antibacterial agents, type of bed padding and their effects on skin surface are also of importance. The influence of bed sheets mainly depends on fibre type, its structure and water absorption. A hypothermic and debilitated patient needs beddings made of low thermal conductivity fibres, which should also effectively transfer the excess of skin moisture to the ambient environment. Irzmińska (Irzmińska et al, 2010) have demonstrated significant differences in blood flow through skin regions particularly susceptible to decubitus ulcers formation.

While discussing the issue of thermal insulation it is also necessary to consider the patient's age. The ability to absorb and lose heat through the skin changes with age. Petrofski et al. investigated a group of subjects in the age range of 20 – 65 years to examine the effect of repeated local heat on skin blood flow and skin temperature over 3 sequential days. In the younger subjects, the blood flow response in the first 20 minutes of heat exposure was over 30% higher than that seen in the older subjects. However, the acclimatization response of the older participants was much slower (Petrofsky et al, 2010). Also, increased cutaneous blood flow helps reduce deep muscle tension (Roberts & Wenger, 1979).

Good effects of insulating use of wool underwear and beddings in patients with fibromyalgia were described by Kiyak (Kiyak, 2009). Almost all patients using wool bed liners and quilts reported significant alleviation of fibromyalgia symptoms. The effectiveness of heat therapy in fibromyalgia was emphasized by Löfgren M. and Norrbrick G. (Löfgren, & Norrbrick, 2009).

Maintaining thermal comfort is also of significant importance in Raynaud's disease. Neutralizing the influence of external temperature with warmers prevents the occurrence of vasoconstriction (Heller, 2006).

Thermal insulation and massage effect of wool fabrics is also important in chronic venous insufficiency. The condition causes blood pooling and congestion resulting in trophic changes, and, consequently, chronic dermatitis (Kelechi & Michel, 2007). Fornalczyk and Kuliński (Fornalczyk & Kuliński, 2008) point out the importance of physical therapy in the prevention and treatment of crural ulceration. The authors emphasize the significance of thermal effects of therapeutic ultrasound.

Following injuries to the extremities, Complex Regional Pain Syndrome often develops, also referred to as **Reflex Sympathetic Dystrophy** Syndrome. Blood vessels constrict due to increased sympathetic activity; thereby the **thermoregulatory** control of **skin** blood flow becomes impaired (Wasner et al, 2000). Maintaining thermal comfort of the dystrophic area helps reduce the suffering.

Vascular disturbances along with autoimmune processes also play a role in the development of neurodegenerative changes in patients with multiple sclerosis. Especially those over the age of 45 might benefit from appropriate thermal insulation to control microcirculation dysfunctions (D'haeseleer et al, 2011).

Peripheral circulation impairment, **manifested by decrease** in **skin temperature**, commonly develops as a complication of peripheral nerve injury. Physical therapy is usually complex; the rate of nerve fibre regeneration depends on providing the tissues of the affected segment with thermal comfort (Druschky, 1979). Standard therapy includes wearing warmers. Satoshi (Satoshi et al, 1991) investigated the effects of a chronic constriction injury to the sciatic nerve of rats accompanied by an abnormality of cutaneous temperature regulation. Pain resulting from peripheral circulation impairment was almost always associated with skin temperature changes. These results emphasize the need to warm the affected extremity. Hornyak et al. (Hornyak et al, 1990) have confirmed the relationship between regional denervation, sympathetic system and blood supply.

Damage to peripheral vessels accompanied by pain is also found in diabetic neuropathy and diabetic foot (PI-Chang, 2006). Providing gentle heat not only helps delay neurological changes but also promotes pain relief.

Pain is frequently associated with sympathetic system stimulation and almost always causes vasoconstriction and a resultant decrease in body temperature (Birklein et al, 1998). Long-term emotional stress may act as an additional factor activating the sympathetic nervous system; it often underlies psychosomatic syndromes including locomotor organ disorders. Dry or moist heat application provides therapeutic benefits (Fechir et al, 2009).

Heat therapy is a standard therapy in soft tissue contractures, which decrease joint mobility. Leung MS and Cheing GL demonstrated several beneficial effects of deep heating in the management of frozen shoulder (Leung & Cheing, 2008). The efficacy of such treatment may be increased by maintaining higher temperature of a given body part with the use of so called shoulder warmers.

Lespargot et al. opt for the use of local and general heat in the treatment of the upper and lower extremities of children suffering from cerebral palsy. Due to excessive muscle tension, using wool beddings might prove extremely beneficial in these children (Lespargot et al, 2000).

Heat, in the form of physical energy, has also been used in rheumatoid arthritis and arthroses. Ayling J. and Marks R. report multiple advantages of heat therapy in rhematoid arthritis especially as procedures preparing the patients to therapeutic exercises (Ayling & Marks, 2000).

Heat therapy procedures are most frequently applied in the treatment of degenerative spine disease. Thus, the importance of wool warmers should not be underestimated.

4. Wool products and their use in some selected disease entities

The use of wool products may be justified and their effect highly beneficial both through heat generation in contact with the skin as well as the prolongation of the thermal effect of therapeutic tissue overheating. Our own pilot studies aimed to determine the effect of natural wool seem to have confirmed the above mentioned benefits. The temperature of the wrist covered with a woolen pad after heat therapy decreased by approximately 1.5 to 2.0°C more slowly compared to the subjects who did not wear such pads. Prolonged tissue temperature elevation helps increase the efficiency of the therapeutic agent.

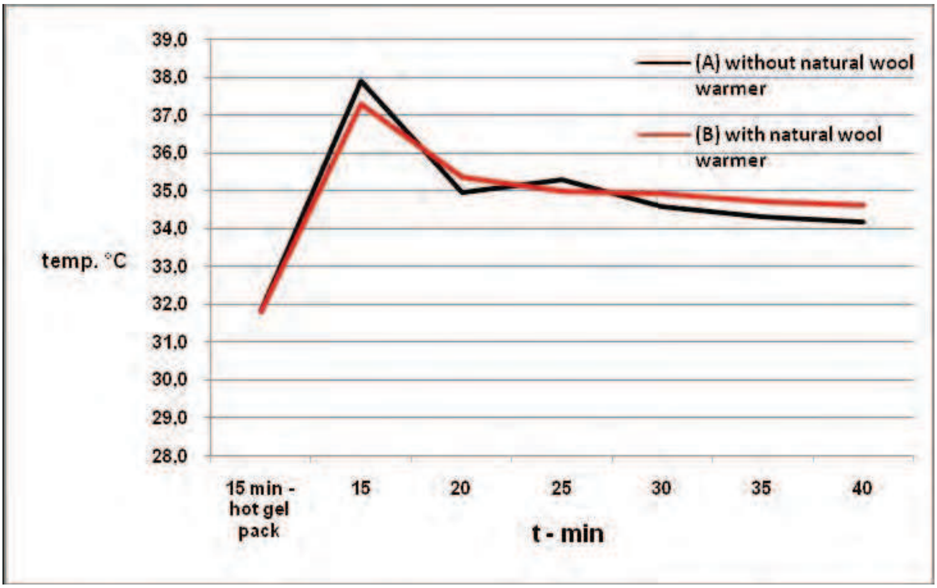


Fig. 2. Sample skin temperature of the carpal region before and after 15-minute hot gel pack with natural wool warmer (group A) compared to hot gel pack alone (group B); ambient temperature 23°C. Own material.

Due to the aforementioned health benefits (cutaneous blood flow improvement, increase of pain threshold and lowering muscle tension), wool products might play a role in preparing tissues for exercise as well as in strengthening the therapeutic effect. The influence of these fabrics on the efficiency and quality of sleep should be again emphasized since sleep has a powerful effect on the body's natural **regenerative processes** both in the case of somatic and psychic problems (depression).

Examples of wool products that may serve therapeutic purposes:

- *Body warmers* – quilts, bedspreads, lumbar belt, elbow, knee and shoulder pads, caps and gloves.

Fig. 3. Body warmers - lumbar belt.

Fig. 4. Body warmers – knee pad.

- Physiotherapy flooring systems – mattresses and mats.
- Neck supports: regular and featured pillows, rolls, seats.

Fig. 5. Featured pillow.

The above products may have preventive or therapeutic, general or local uses (depending on product type) in the following conditions and disease entities:

- rheumatoid inflammatory disease - rheumatoid arthritis, ankylosing spondylitis;
- degenerative joint disease – coxarthrosis, gonarthrosis;
- degenerative disease of intervertebral joints – spondyloarthrosis;
- systemic connective tissue disorders (lupus erythematosus, systemic sclerosis);
- fibromyalgia;
- decubitus ulcers prevention;
- muscle, tendon, ligament, fascia and muscle-tendon attachment inflammatory conditions, eg., lateral epicondilitis (tennis elbow) medial epicondilitis (golfer’s elbow);
- shoulder pain (impingement) syndrome, frozen shoulder;
- primary or secondary peripheral circulation disorders (skin, muscles);
- lower limb ischaemia;
- Sudeck's atrophy (reflex sympathetic dystrophy syndrome);
- diabetes-related pathology of the skin, muscles and the circulatory and nervous systems;
- peripheral nerves and brachial plexus paralysis;
- infantile cerebral palsy;
- wheelchair-bound patients with lower limb paralysis and trophic changes – seat or backrest padding;

- bone tissue disorders (osteoporosis, osteomalacia)
- depressive disorders.

Types of therapeutic interventions following which wool products should be used to prolong the thermal effect produced:

- partial paraffin bath;
- paraffin pack;
- warming gel packs;
- thermophore heating pack;
- Kenny's method of treating polio: hot packs, most heat wraps;
- electrotherapy – electric current is applied to decrease pain and muscle tension, e.g., diadynamic currents DF, CP, LP
- ultrasounds;
- shortwave diathermy;
- Sollux lamp infrared irradiation;
- classical massage;
- whirlpool and underwater massage.

Fig. 6. Extension of the thermal effect using a lumbar belt after diadynamic current treatment.

Wool fabrics are most frequently used in the following functional disorders accompanying the above mentioned disease entities:

- increased or decreased muscle tension;
- paralysis and paresis;
- pain syndromes;
- peripheral vascular disease (especially of arterial and lymphatic vessels);
- sensorimotor disorders;
- morning stiffness pain.

Contraindications to wool products:

- all acute inflammatory conditions of soft tissues and locomotor organs;
- decubitus ulcers and other skin lesions;
- allergy to natural fabrics.

Other remarks:

Wool products used by infants, young children and individuals oversensitive to wool should be wrapped in cotton covers which prevent wool fibres from entering the eyes, and nasal / oral cavity.

5. Summary and conclusions

A considerable number of diseases are concurrent with primary or secondary peripheral, cutaneous and muscular circulation disorders. For example, primary circulatory disturbances result from peripheral vascular disease, which commonly affects the arteries supplying the leg and is mostly caused by atherosclerosis. Secondary changes occur in patients with limb paresis or paralysis following stroke, peripheral nervous system injury as well as in those suffering from muscle tension increase due to chronic pain (Moncur & Shields, 1987: Strass et al, 2002). Whether primary or secondary, the disorders result in reduced arterial and venous blood supply associated with lowered lymph flow dynamics.

All patients diagnosed with the above mentioned circulatory impairments (except those with accompanying acute inflammatory conditions) might benefit from the prevention of heat loss through the affected body part. It should be remembered that heat loss is directly proportional to the **temperature gradient between** the **skin** and surrounding environment (Straburzyński & Straburzyńska, 2000). Thus, the reduction of heat loss emerges as the basic objective of therapeutic interventions. The rate of peripheral nerve regeneration is positively affected by the temperature of surrounding tissues and metabolism, which directly depends on peripheral, and even capillary circulation (Straburzyński & Straburzyńska, 2000).

Thus, doctor's and physiotherapist's recommendations regarding the use of body warmers should be considered highly advisable from the medical point of view. Warmers enhance the capability of moisture absorption and ensure air exchange of the body part with its surroundings without excessive heat loss. Heat accumulates in the affected site and, through warming, entails its therapeutic effects. Increased sweating during exercise does not cause unpleasant cooling effects since **wool** fiber molecules **generate heat**.

Another important property of wool fibres is the **mechanical effect** in contact with the **skin**. Non-irritating roughness of wool fabrics induces beneficial mechanical stimulation of sensory receptors. Micromassage of reflex points and resulting **cutaneous vascular** responses stimulate microcirculation and β-endorphin secretion. Thereby, the sensation of pain becomes diminished (Bender et al, 2007; Grass, 1982; Strass et al, 2002; Wright & Slukak, 2001). It should be emphasized that the majority of locomotor system and visceral diseases, and especially chronic problems, cause certain areas of the skin (Head's zones) to develop microcirculation disturbances and hyper- or hypoesthesia through segmental spinal reflexes. These sensation disorders result in secondary ailments (alternative pathways of pathological stimulation). The above mentioned micromassage by wool fabrics facilitates the elimination of such unpleasant sensations. Roughness and thermal insulation also prove very advantageous during therapeutic exercise. It should also be remembered that different types of wool covers used on physiotherapy tables or floors additionally stimulate the skin, and thus perfectly enhance the effects of sensory integration therapy, and especially in children with neurological defects.

Therapeutic benefits of wool-covered orthopaedic appliances (e.g., neck supports) mainly depend on whether they are ergonomically designed. Adherence to biomechanical principles, i.e., appropriate size, shape and hardness of collars and belts used by individuals suffering from shoulder or spinal pain syndromes, ensures efficient sleep. These supports are also used during massage, physiotherapy and kinesitherapy interventions.

To sum up: the presented thermal, mechanical and ergonomic advantages of wool and specialist wool fabrics provide a large body of evidence to confirm that several properties of wool products facilitate the treatment and relief of numerous diseases and can thus be successfully used in medical care and **rehabilitation**.

Although specialist wool products alone may not be sufficient to achieve preventive and therapeutic objectives, they can certainly deliver excellent results as supplements to heat therapy, cryotherapy, electrotherapy and massage. The body's response to physical therapy lasts longer which results in shorter recovery time and lowers the costs of treatment.

6. References

[1] Avidan, AY. Zee, PC. (2007). *Sleep medicine handbook*. A. Wichniak, (Ed.), MediPage , ISBN 83-89769-50-3, Warsaw

[2] Ayling J, Marks, R. (2000). Efficacy of Paraffin Wax Baths for Rheumatoid Arthritic Hands. *Physiotherapy,* Vol. 86, No. 4, pp. 190-201, ISSN 0031-9406

[3] Bach, V. Telliez, F. & Libert, JP. (2002). The interaction between sleep and thermoregulation in adults and neonates. Sleep *Medicine Reviews*, Vol. 6, No. 6, December 2002, pp. 481-492, ISSN: 1087-0792

[4] Bender, T. Nagy, G. Barka, J. et all. (2007). The effect of physical therapy on beta – endorphin levels, *Europen Journal of Applied Physilogy,* Vol. 100, No. 4, pp. 371 – 82

[5] Beuth, B.(1968). *Textile materials technology*. Publisher of Light Industry and Food, Warsaw, Poland

[6] Birklein, F. Riedl, B. Neundörfer, B. & Handwerker, H. (1998). Sympathetic vasoconstrictor reflex pattern in patients with complex regional pain syndrome. *Pain,* Vol. 75, No. 1, pp. 93-100, ISSN: 0304-3959
[7] Bochenek, A. & Reicher M. (1989). Innervation of the skin. In: *Human Anatomy*. pp. 361-375, PZWL, ISBN 83-200-1230-9, Warsaw, Poland
[8] Chen, D.; Tan, L. Liu, H. Hu, J. LI, Y.& Tang F.(2010). Fabricating superhydrofilic wool fabrics. *Langmuir,* Vol. 26, No. 7, pp. 4675-4679, ISSN 0743-7463
[9] Ciesielska, I. Mokwiński, M. & Orłowska-Majdak, M. (2009). Influence of different kind of clothing material on selected cardiovascular, respiratory and psychomotor parameters during moderate physical exercise. *International Journal of Occupational Medicine Environmental Health,* Vol. 22, No. 3, pp. 215-226
[10] D'haeseleer, M. Cambron, M. Vanopdenbosch, L. De Keyser, J. (2011).Vascular aspects of multiple sclerosis. *Lancet Neurology,* Vol 10, pp. 657–66
[11] Druschky, KF.(1979). Conservative treatment of peripheral nerve lesion. *Fortschritte Der Medizin*, Vol. 97, pp. 1185-90
[12] Fechir, M. Schlereth, T. Kritzmann, S. Balon, S. Pfeifer, N. Geber, C. Breimhorst, M. Eberle, T. Gamer, M. & Birklein, F. (2009). Stress and thermoregulation: different sympathetic responses and different effects on experimental pain. *European Journal of Pain,* Vol. 13, No. 9, pp. 935-41, ISSN: 15322149
[13] Field, T. Robinson, G. Scafdi, F. Nawrocki, T. Goncalves, A. Pickens, J. Fox, N. Schanberg, S. Kuhn, C. (1996). Massage therapy reduce anxiety and enhances eeg pattern of alertness and match computations. *International Journal of Neuroscience,* Vol. 86, No. 3-4, pp.197 – 205
[14] Fornalczyk – Wachowska, E, Kuliński, W. (2008). Physical methods for prophylaxis and treatment of venous leg ulcers. *Acta Balneologica*, Vol. 50, No. 2, pp. 86-92
[15] Gieremek, K. Saulicz, E. & Nowotny, J. (1991). Local and reflexes changes in skin temperature under the influence of selected physical treatments. *Advances in Rehabilitation,* Vol. V, No. 3
[16] Gilbert, S. Cameron, J. Sally, A. & Drew, D. Thermoregulation as a sleep signaling system. *Sleep Medicine Reviews,* 2004, Vol. 8, No. 2, pp. 81-93, ISSN: 1087-0792
[17] Grass, D. (1982). Physical therapy and rheumatism of soft tissues. *Schweizerische Medizinische Wocheuschrift* , Vol. 112, No. 350, pp.1214 – 8
[18] Grycewicz, H.& Staniszkis, O. (1959). Wool. National Agricultural and Forestry Publisher, Warsaw, Poland
[19] Heller, HC. (2005). Temperature, Thermoregulation, and Sleep. In: *Principles and Practice of* Sleep *Medicine (Fourth Edition)*, Kryger, Meir H. Roth, Th. Dement, W C. pp.292-304, Saunders, ISBN 0721607977
[20] Heller, P.E. & Shear, N.H. (2006). Temperature-dependent skin disorders. Construction and Building Materials, Vol. 20, No. 6, July 2006, pp. 425-434, ISSN: 0950-0618
[21] Hornyak, ME. Naver, HK. Rydenhang, B. & Wallin, BG. (1990). Sympathetic activity influences the vascular axon reflex in the skin. *Acta Physiologica Scandinavica,* Vol. 139, No. 1-2, pp. 74-84

[22] Irzmańska, E. Lipp-Symonowicz, B. Kujawa, J. & Irzmański R. (2010). Textiles Preventing Skin Damage. *Fibres and Textiles in Estern Europe*, Vol. 18, No. 2 (79), pp. 84-90

[23] Kelechi, TJ, & Michel, Y. (2007). A descriptive study of skin temperature, tissue perfusion, and tissue oxygen in patients with chronic venous disease. *Biological research for nursing,* Vol. 9, No. 1, pp. 70-80, ISSN: 1099-8004

[24] Kiyak, EK. (2009). A new nonpharmacological method in fibromyalgia: the use of wool. *Journal of alternative and complementary medicine, Vol.* 15, No. 4, pp. 399-405

[25] Kun, Qian. Hongshun, Li. Haijian, Cao. Kejing, Yu. & Wei, Shen. (2010). Measuring the Blend Ratio of Wool/Cashmere Yarns Basedon Image Processing technology. *Fibres and Textiles in Eastern Europe,* Vol. 18, No. 4 (81), pp. 35-38

[26] Lespargot, A. Robert, M. & Khouri, N. (2000). Stretching the triceps surae muscle after 40 degrees C warming in patients with cerebral palsy. *Revue de chirurgie orthopédique et réparatrice de l'appareil moteur*, Vol. 86, No. 7, pp.712-7

[27] Leung, MS. & Cheing, GL. (2008). Effects of deep and superficial heating in the management of frozen shoulder. *Journal of Rehabilitation Medicine,* Vol. 40, No. 2, pp. 145-50

[28] Li Y. (2005). Perceptions of temperature, moisture and comfort in clothing during environmental transients. *Ergonomics*, Vol. 48, No. 3, pp. 234-48, ISSN 0014-0139

[29] Löfgren, M. & Norrbrink, C. (2009). Pain relief in women with fibromyalgia: a cross-over study of superficial warmth stimulation and transcutaneous electrical nerve stimulation. *Journal of Rehabilitation Medicine*, Vol. 41, No. 7, pp. 557-62

[30] Matusiak, M. (2010). Thermal Comfort Index as a Method of Assessing the Thermal Comfort of Textile Materials. *Fibres and Textiles In Easter Europe*, Vol. 79, No. 2, pp. 45 – 50

[31] Moncur, C. Shields, MM. (1987). Physiotherapy methods of reliving pain. *Baillieres Clinics Rheumatology, Vol.* 1, No 1, pp. 183-93

[32] Petrofsky, J. Bains, G. Prowse, M. Gunda, S. Berk, L. Raju, C. Ethiraju, G. Vanarasa, D. & Madani, P.(2009). Does skin moisture influence the blood flow response to local heat? A revoluation of the Pennes model. *Journal of Medicine Engineering and Technologies,* Vol. 33, No. 7, pp. 532-537, ISSN: 1464-522X

[33] Petrofsky, J. Goraksh, N. Alshammari, F. Mohanan, M. Soni, J. Trivedi, M. Lee, H. Hudlikar, AN. Yang, CH. Agilan, B. Pai, N. Chindam, T. Murugesan, V. Eun, Yim, J. & Katrak, V. (2010). The ability of the skin to absorb heat; The effect of repeated exposure and age. *Medical science monitor,* 2010 Dec 16;17(1):CR1-8, Available from www.ncbi.nlm.nih.gov

[34] Petrofsky, JS. Bains, G. Raju, C. Lohman, E. Prowse, M. Gunda, S. Madani, P. & Batt, J. (2009).The effect of the moisture content of a local heat source on the blood flow response of the skin. *Archives of Dermatological Research,* Vol. 301, No.8, pp.581-585. Epub 2009 May 5, ISSN: 0340-3696

[35] Pi-Chang, Sun. Hong-Da, Lin. Shyh-Hua, Eric Jao. Yan-Chiou, Ku. Rai-Chi, Chan. & Cheng-Kung Cheng. (2006). Relationship of skin temperature to sympathetic dysfunction in diabetic at-risk feet. *Diabetes Research and Clinical Practice.* Vol. 73, No.1, pp. 41-46, ISSN: 0168-8227

[36] Roberts, MF. & Wenger, CB. (1979). Control of skin circulation during exercise and heat stress. *Medicine and science in sport, Vol.* 11, No. 1, pp. 36-41

[37] Satoshi, W. Kajander K.C. & Bennett G.J.(1991). Abnormal skin temperature and abnormal sympathetic vasomotor innervations, in an experimental painful peripheral neuropathy. *Pain* Vol.46, No.3, September 1991, pp. 299-313, ISSN: 0304-3959

[38] Sefton, JM. Yarar, C. Berry, JW. & Pascoe, DD. (2010). Therapeutic massage of the neck and shoulders produces changes in peripheral blood flow when assessed with dynamic infrared thermography. *Journal of Alternative and Complementary Medicine*, Vol. 16, No. 7, pp. 723-732 ISSN: 1075-5535

[39] Shafik, A. (1993). Polyester but not cotton or wool textiles inhibit hair growth. *Dermatology,* Vol. 187, No. 4, pp. 239-242

[40] Shafik, A. (2008). An experimental study on the effect of different types of textiles on conception. *Journal of Obstetrics and Gynecology,* Vol. 28, No. 2, pp. 213 – 6

[41] Skanderi, Z. Salopek – Ćubrić, I. & Sdrjak, M. (2009). Water vapor permeability in a variety of climatic conditions. *Fibres and Textiles In Easter Europe*, Vol. 17, No. 2(73), pp. 72 – 75

[42] Straburzyńska – Lupa, A. & Straburzyński G. (2000). Thermotherapia. In: *Physiotherapy.* PZWL, ISBN 83-200-3372-1, Warsaw, Poland

[43] Strass – Blasche, G. , Ekmekcioglu, C. Vacariu, G. Melchart, H. Fialka-Moser, V. & Marktl, W. (2002). Contribution of individual spa therapies in the treatment of chronic pain; *The Clinical Journal of Pain, V*ol. 18, No. 5, pp. 302-9, ISSN 0749-8047

[44] Sudoł – Szopińska, I. & Chojnacka, A. (2007). Determination of conditions for indoor thermal comfort using the PMV and PPD indices. *Work Safety,* Vol.5, pp.19-23

[45] Szymusiak, R. Thermoregulation during Sleep and Sleep Deprivation. In: Encyclopedia of Neuroscience, 2009, pp: 971-975

[46] Tourula, M. Fukazawa, T. Isola, A. Hassi, J. Tochihara, Y. & Rintamäki, H. (2010). Evaluation of the thermal insulation of clothing of infants sleeping outdoors in Northern winter. *European Journal of Applied physiology*, Vol. 111, No. 4, pp. 633-640, ISSN: 1439-6319

[47] Tsuzuki, K. Okamoto-Mizuno, K. Mizuno, K. (2004). Effects of humid heat exposure on sleep, thermoregulation, melatonin, and microclimate. *Journal of Thermal Biology*, Vol. 29, No.1, January 2009, pp. 31-36, ISSN 0306-4565

[48] Wasner, G. Schattsschneider, J. Heck Mann, K. Maier, C. Baron, R. (200). Vascular abnormalities in reflex sympathetic dystrophy (CRPS I): mechanisms and diagnostics value. *Brain a journal of neurology*, Vol. 124, No. 3, pp. 587-99

[49] Wollina, U. Abdel-Naser, MB. & Verma, S. (2006). Skin physiology and textiles-consideration of basic interactions. *Current Problems in Dermatology.* Vol. 33. pp. 1-16, ISSN: 1421-5721

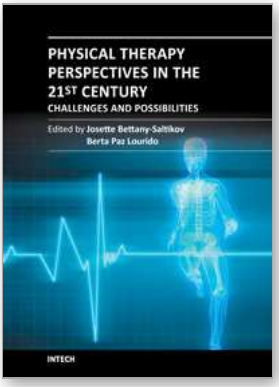
[50] Wright, A. & Slukak, A. (2001). Nonpharmacological treatment for muscoskeletal pain. *The Clinical Journal of Pain,* Vol. 17, No. 1, pp. 33-46, ISSN 0749-8047

[51] Xu, F. Lu, TJ. & Seffen, K.A. (2008). Biothermomechanics of skin tissues. *Journal of the Mechanics and Physics of Solids,* Vol. 56, No. 5, pp. 1852-1884, ISSN: 0022-5096

[52] Yiming, G. Ling, Ch. Xing, D.& Ning, P. (2010). Blood flow fluctuation underneath human forearm skin caused by local thermal stimuli of different fabrics. *Journal of Thermal Biology.* Vol. 35, No. 7, (October 2010), pp. 372-377, ISSN: 0306-4565

[53] Ziemniewska, M. Laurentowska, M. Bogacz, E. Kryscik, J. Domaszewska, K. & Ziemniewska, O. (2010). Influence of sportswear made from polyester and man-made cellulosic fibres on the energy cost of physical effort, *Fibres and Textiles in Eastern Europe,* Vol. 18, No. 3, pp. 94-99

[54] Żyliński, T. (1958). Learning about fiber. Publisher of Light Industry and Food, Warsaw, Poland



Physical Therapy Perspectives in the 21st Century - Challenges and Possibilities

Edited by Dr. Josette Bettany-Saltikov

ISBN 978-953-51-0459-9
Hard cover, 386 pages
Publisher InTech
Published online 05, April, 2012
Published in print edition April, 2012

This book contains new information on physical therapy research and clinical approaches that are being undertaken into numerous medical conditions; biomechanical and musculoskeletal conditions as well as the effects of psychological factors, body awareness and relaxation techniques; specific and specialist exercises for the treatment of scoliosis and spinal deformities in infants and adolescents; new thermal agents are being introduced and different types of physical therapy interventions are being introduced for the elderly both in the home and clinical setting. Additionally research into physical therapy interventions for patients with respiratory, cardiovascular disorders and stroke is being undertaken and new concepts of wheelchair design are being implemented.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Krzysztof Gieremek and Wojciech Ciesla (2012). Natural Wool Fabrics in Physiotherapy, Physical Therapy Perspectives in the 21st Century - Challenges and Possibilities, Dr. Josette Bettany-Saltikov (Ed.), ISBN: 978-953-51-0459-9, InTech, Available from: http://www.intechopen.com/books/physical-therapy-perspectives-in-the-21st-century-challenges-and-possibilities/natural-wool-fabrics-in-physiotherapy

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821