THE HONG KONG POLYTECHNIC UNIVERSITY
INSTITUTE OF TEXTILES AND CLOTHING

EFFECT OF HEAT AND MOISTURE TRANSFER PROPERTIES OF T-SHIRTS ON COMFORT SENSATIONS

Kar Fung Yi

A thesis submitted in partial fulfilment of the requirements

for the Degree of Master of Philosophy

December 2006

I hereby declare that this thesis is my own work and that, to the best of

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

Kar Fung-yi

Dedicate to: My Parents & Friends

ABSTRACT

The heat and moisture transfer properties of clothing are critical to thermal comfort as they affect the direct (viz. heat transfer by conduction, convection, radiation) and latent (viz. evaporative heat) heat loss from the human body. The objective measurement of the heat and moisture transfer properties of clothing and the understanding on how they affect thermal comfort sensations are therefore important to apparel product development.

The present study is focused on the objective measurement of the heat and moisture transfer properties of T-shirt fabrics and garments and the investigation of the relationship between these objectively measured properties and the thermal comfort sensations of T-shirts in wear.

In one part of this study, different types of laboratory tests for the moisture transport properties of fabrics and garments were compared. These tests include ASTM E96 Water Vapor Transmission Test, Moisture transmission Test (Model CS-141), Sweating Guarded Hot Plate Measurement, and the sweating fabric manikin-Walter. For the range of knitted T-shirt fabrics tested, it showed that results from the different tests are highly interrelated. The correlations established from this study make it possible to compare test results from different test methods.

In another part of the study, the physiological responses (i.e. measured in terms of mean skin temperature and humidity) and thermal comfort sensations for human subjects wearing T-shirts made of 14 different types of fabrics and undergoing a protocol of running exercise were investigated. The study showed that, although the

differences in terms of the physiological responses, between the wearers wearing different T-shirts, are not statistically significant probably due to the large variances in human subjects' physiological conditions and variances in wearer trials, there are significant differences between the thermal comfort votes for human subjects wearing different T-shirts. Human is more sensitive than the temperature and humidity measurements because of unobvious differences between the T-shirt fabric samples.

Based on the Principle Component Analysis and Multiple Regression Analysis, the study further showed that thickness and thermal properties were important predictors of the thermal comfort sensations of wearers during and after the exercise, whereas moisture transport properties of fabrics are not important factors to thermal comfort at the initial period of the exercise, but become more important after the initial period. Towards the end of the exercise and after the exercise, when the wearers sweated, liquid water absorbency and wicking properties become significant predictors of thermal comfort sensation. In addition, it was found that, at the beginning of the exercise, overall thermal comfort sensation is mainly related to the warmth sensation and towards the end of the exercise and after the exercise, the overall thermal comfort sensation is increasingly related to skin wetness sensation.

LIST OF PUBLICATIONS

Conference Presentations:

- Kar, F., Fan, J. and Yu, W., 'Effects of the Properties of T-shirts on Wearers' Comfort Sensations', *Proceedings of the 3rd European Conference on Protective Clothing (ECPC) and NOKOBETEF 8*, 10-12 May 2006, Gdynia, Poland.

Book Chapter:

- Kar, J., Fan, J. and Yu, W., 'Chapter 9: Performance evaluation of knitted underwear', *In:* W. Yu and J. Fan, (ed). *Innovation and Technology of Women's Intimate Apparel*, 2007, Cambridge: Woodhead Publishing Limited. pp. 196-222.

Papers to be Submitted:

- Kar, F., Fan, J. and Yu, W., 'Comparison of Different Test Methods for the Measurement of Fabric or Garment Moisture Transfer Properties', 2007.

- Kar, F., Fan, J. and Yu, W., 'Effects of Thermal and Moisture Transport Properties of T-shirts on Wearer's Comfort Sensations', 2007.

ACKNOWLEDGEMENTS

This project is funded by the ITSF project. Many thanks to the Hong Kong Government and the industrial sponsors including TAL Apparel Limited, Textile Manufacturing Technology Testing Centre Limited, Intertek Testing Services Hong Kong Ltd., Nylstar Hong Kong Ltd., Esquel Group, Bonluxe (Asia) Limited, Solutions Health Care Products & Services Ltd., and P.H. Garment Mfg. Co. Ltd.

I would like to express my deepest gratitude and appreciation to my chief supervisor, Prof. Jintu Fan, for giving me such a good opportunity to study here and his patient guidance throughout this research. Without his expertise advice and helpful guidelines, this research would not be possible.

Deepest thanks also to my co-supervisor, Dr. Winnie Yu, who gave me so many academic advices and opportunities to be involved in writing a book chapter.

Sincere appreciation is conveyed to Mr. Kung, the pattern technician of ITC, for his skillful pattern making of the experimental T-shirt garments, and Mrs. Amy Pang, garment technician of ITC for her guidelines for sewing the T-shirts, as well as the laboratory technicians Mr. Choi and Ms. Sun, for their kind special arrangement and guidelines of different kinds of measurements.

Special thanks are given to Mr. Robin Wan for his assistance in conducting the Walter tests, and Koeman for his assistance in conducting the Moisture Transmission Test. Many thanks to Mr. Ah Pun Chan, Mr. Kevin Wong, Mr. Kit Ho and Mr. Roy Lai for participating in the wearer trials.

I would also like to say thank you to my ITF team members for their support and assistance to my research.

Last but not the least, thanks also given to my family and friends for the love and encouragement throughout this period.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

FIGURES:

CHAPTER 2

CHAPTER 3

CHAPTER 5

TABLES:

CHAPTER 2

CHAPTER 3

.

CHAPTER 4

CHAPTER 5

LIST OF APPENDICES

CHATER 1

INTRODUCTION

1.1 Research Background

Thermal comfort is dependent on the efficiency of heat dissipation from a clothed human body [1]. It is insufficient to maintain the thermal balance between the human body and the environment only by the human thermoregulatory system, so it is essential to wear clothing to act as a barrier or facilitator to the heat transfer process. The ability of clothing is dependent on the heat and moisture transfer properties such as the parameters of thermal insulation and moisture vapour resistance which are influenced by many factors such as materials, designs and construction [2]. The thermal properties of clothing is used to assist human body to maintain a thermal balance between the metabolic heat which it generated and lost to the environment through the heat transfer by conduction, convection, radiation and evaporation [3 - 7]. Thus, a strong relationship can be found between clothing properties, physiological and psychological sensations.

As clothing comfort is a popular topic nowadays, many researchers conducted investigations in this area. In 1980s, Fuzek [8] and DeMartino [9] tried to relate the subjective comfort to different clothing factors including the mechanical properties, fitness and some thermal properties of T-shirts. However, it showed no significant relationship between the moisture and thermal properties of T-shirts and comfort sensations. It is because the conditions of subjective wearer trials were not conducive to differentiate the differences of the thermal functions of the T-shirt samples. Scheurell [10] et al. later used a variety of fabrics and environmental conditions to investigate the relationship between the dynamic surface wetness of knit sport shirtings and subjective moisture comfort sensations and a high relationship was found. In a more comprehensive research which involved several kinds of fabric properties, Li [11] et al. applied Principle Component Analysis to combine the fabric properties into three factors, each of which represented a group of fabric properties. It also showed that relating comfort sensations to these three factors was more meaningful to each individual property

Recently, Yoo and Barker [12] suggested to analyze the results with different stages of activities and also under different environmental conditions. They found that the moisture related properties were important just under hot and humid conditions and in the cool down period, but for the other periods or conditions, tactile properties became more important. Thus, it is necessary to analyze the relationships at different levels of activities.

Although considerable investigations have been carried out in this area, a better understanding of the relationship between the fabric/garment properties and thermal comfort sensations are required, particularly in view of the many newly developed functional fabrics and the development in the thermal manikin technology for quantifying the thermal and moisture transfer properties of garments.

1.2 Objectives

This project aims to investigate the relationships between the thermal comfort sensations and the heat and moisture transfer properties of T-shirts and, in addition, the interrelationships between different test methods for the thermal and moisture transport properties of fabrics and garments, in particular:

1) To compare the subjective thermal comfort sensations and thermal properties of men's T-shirts made of different types of materials by wearer trials, thermal manikin and laboratory tests;
2) To investigate the correlation between the subjective thermal comfort sensations and the objective heat and moisture transfer properties of men's T-shirts;
3) To investigate the interrelationships between the test results from different objective thermal and moisture transfer measurements.

1.3 Scope of the Study

This study covers all common thermal properties of men's T-shirts that claimed to offer functional thermal comfort. Physiological responses and human comfort sensations were investigated by objectively measuring the skin temperature and humidity and rating the subjective psychological scales, respectively.

1.4 Significance of the Study

The outcome of this research project can be used as a reference for the clothing manufacturers to better evaluate the wearers' comfort sensations of clothes by using

Walter sweating mannequin and other laboratory tests. Manufacturers can improve the comfort of new clothing products by improving fabric and garment's thermal and moisture transport properties. This study also serves a benchmark for evaluating the new functional fabrics of different constructions.

1.5 Outlines of the Study

There are six chapters in this thesis.

Chapter 1 introduces the research purposes and scope of study. Research background, objectives, the project significance is also highlighted.

Chapter 2 provides a thorough review of the literature about thermal comfort, thermophysiology, moisture heat transfer mechanism and properties. Recent developments of functional knitted T-shirt fabrics and their relationships among comfort sensation, clothing properties and thermoregulatory responses are reported.

Chapter 3 explains the research methodology and fabric samples in details. The use, testing procedures and analysis methods of both the objective and subjective testing methods are described.

The testing results of objective laboratory tests, subjective perceptions and thermoregulatory responses are reported in Chapter 4 with comparison of different fabric samples.

Chapter 5 reports the relationship among different clothing properties, moisture transmission tests, subjective comfort sensations, physiological responses and subjective comfort sensations.

Chapter 6 summarizes the conclusions and limitations of the study. Recommendations on further studies are also provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Before investigating the relationship between different clothing properties and comfort sensations, it is necessary to understand the heat and moisture transfer mechanism of clothing, human physiological system and the human comfort perceptions.

2.2 Thermal comfort

Comfort is defined in the Oxford English Dictionary as “State of being free from suffering, anxiety and/or pain; contentment; or physical well-being”. Thermal comfort is by definition a subjective sensation, which is a psychological phase but not a physiological state. It is individualistic so that acclimatization can change the skin temperature at which a person feels too hot or too cold and it may be influenced by individual mood, personality, culture background and social factors [2, 3].

2.2.1 Basic Theory

Ishtiaque [13] and Wang [14] had suggested several functional requirements which are found applicable to the comfort aspects of general garment (Table 2.1)

Table 2.1 Functional Requirements of clothing [13,14]

- To maintain a comfortable microclimate in terms of temperature and humidity in the skin sensory zone.
- Good moisture/liquid water absorption and water vapour transmittance in order to keep the next-to-skin surface dry.
- Absence of unpleasant odour such as perspiration.
- Compatibility with the skin.
- Good extensibility without restricting mobility.
- Good fit stability.
- Low intrinsic weight (not impairing physical performance).
- Fabric substantially water-repellent and dirt-repellent.
- Reusable with easy care such as laundering without shrinkage.

Thermal comfort is primarily related to the efficiency of heat dissipation from a clothed human body [1] and is rated as the "neither too hot nor too cold" feeling of the wearer. The body is in a state of comfort when the core temperature of the body is maintained at 37^{o}C $\pm$ 0.5 ^{o}C and the average skin temperature is approximately 33^{o}C without the presence of sweat [15]. The maximum deviations of the core temperature are about 2 from its normal level. Otherwise, serious physical threats such as hyperthermia, hypothermia and cardiac fibrillation of low core temperature would occur. Survival problem would be presented if there are more extreme variations (a rise or fall of 5^{o}C) in core temperature [16,17].

Thermal comfort can be defined mathematically using Fanger's model [18] which stated the basic equation of thermal balance. The equation is shown below:

$$S = M - L_{cond} - L_{radi} - L_{conv} - L_{evap} - W \qquad (2.1)$$

Where, M is the metabolic energy production in human body, W is the external work, L_{cond}, L_{radi}, L_{conv}, L_{evap} are the heat loss by conduction, radiation, convection and evaporation, S is the rate of heat storage in the tissues. All are in units of W.

Under thermal equilibrium, S would be equal to zero that the thermal comfort is arrived.

Fanger [18] defines three conditions for a person to be in (whole-body) thermal comfort:

- the body is in heat balance;
- sweat rate is within comfort limits; and
- mean skin temperature is within comfort limits.

Human body would exchange the energy with the clothing system and environmental conditions in different forms of heat transfer. The wearer would have thermal comfort when the Human-Clothing-Environment system reaches a steady state and the physiological thermal neutrality is arrived [14]. Hollies [19] had demonstrated that there is little sweat or saturated water vapour produced by human body under normal stationary conditions and the wearer doesn't experience any significant discomfort while wearing a either cotton or polyester shirt. However, this steady state would be influenced by a sudden change of the environment such as going-out from an air-conditioned room to a hot and humid outdoor environment, a sudden discharge of considerable amount of liquid from the body, and the change of physical activities with different metabolisms [14].

Thermal comfort is one of important factors in the determination of the comfort properties of fabrics. Cheng and Cheung [1] and Hardy et al. [20] have discussed the effect of clothing on thermal comfort with a fundamental review of relevant fabric properties and other external factors. They stated that the effect of clothing on thermal comfort depended mainly on the following factors:

- the body’s internal metabolism for production of heat general level of activity, physical exercise, external heat sources like the sun, etc;
- physical properties of fabrics/clothing to moisture, water or air, etc;
- the air spaces between the skin and the fabric, or between the fabrics themselves, and
- the characteristics of the environment, e.g. mean radiant temperature depending on air temperature, body temperature, relative air velocities and water vapor pressure in ambient air.

Qian [2] stated that the ability of clothing is acting as an assistance of human body for adjusting the rate of energy exchange, so an ideal clothing for thermal comfort is able to allow the wearer to feel comfortable in as a wide range of environments and physical activity as possible.

Mehrtens and McAlister [21] assumed that the comfort can be predicted by the scratchiness, warmness and heaviness, and clinginess feelings, viz.

$$\text{Comfort} = f(\text{scratchiness}) + f(\text{warmness and heaviness}) + f(\text{clinginess}) \qquad (2.2)$$

And they modified the equation with clothing properties by objective tests:

$$\text{Comfort} = f(\text{scratchiness sound}) + f(\text{fabric weight x thickness}) + f(\text{clinging tension}) \quad (2.3)$$

Moisture comfort is dependent on the dampness sensations which are recommended as a sensitive tool to evaluate the thermal function of garments according to the subjective sensations of wetness of skin and clothing [22]. Heat generation is an outcome of skin-cloth rubbing in order to dissipate frictional energy and is certainly a main cause of skin burnt, irritation and blister formation [23]. This is particularly important for T-shirt worn during exercise or other physical activities with high body movement. During exercise, the body temperature will rise faster. With the presence of sweats on the skin surface, the body temperature will drop a little bit as the sweats act to assist for heat transfer [15]. The heat is dissipated by sweat evapouration which occurs depending on the relevant vapour pressure gradients (of the skin, air, clothing and ambient environment) [24], but the body temperature drops even faster after exercise [25]. As a result, the irritation and skin damage can be prevented. However, Ruckman and Green [26] stated that an undershirt may be comfortable to wear when dry, but it could become extremely uncomfortable when soaked in perspiration. Sweeney and Branson [27] stated that moisture or sweats sensation in clothing were only one of the many sensations impacting judgments of clothing comfort. Although humans have no humidity receptors, in some way the wetness of the skin is also sensed, and can be related to the evaluation of comfort and discomfort [28]. This has been confirmed by Hollies [29] who found that the sensations of loss in comfort occurred if there was sweating. When more than 50-65% of the body surface is wet, discomfort is experienced [15]. However, in normal stationary conditions, there are little sweat or saturated water vapor produced by the human body, so the wearer may be difficult to experience any significant difference in comfort while wearing clothing with different water vapor transmission performance [5].

Cotton is the most common material used to manufacture T-shirt. It was found that cotton was associated with both physical and psychological comfort, and was rated as youthful, honest, pure and dependable [30]. From the Australians' perspective, cotton is seen to be close to the ideal material for making sportshirts - the only disadvantage of cotton is that it is crushable [31]. Boslet [30] has also stated that it was difficult to find any fibre matching the advantages of cotton. However, cotton exhibited more broken fibres after abrasion and greater flexural rigidity. Furthermore, cotton could be more likely to cause skin irritation. On the other hand, other Knitted T-shirts materials, nylon and polyester are regarded as artificial, insincere, low quality, unfashionable, clammy, sweaty, clingy, synthetic and itchy [30, 31]. In recent years, the scene has totally changed. A number of studies have shown that by using appropriate yarn and fabric structures, clothes made by synthetic fibres can be as comfortable to wear as those made by natural fibres, especially the newly developed polyester fabrics [24, 26, 32 - 35]. However, neither the synthetic nor cotton fabrics represent a thermoregulatory, physiological, or comfort sensation disadvantage when compared to a seminude ensemble [36].

2.2.2 Evaluation

When people feel certain sensations such as coldness or dampness to the contact of their clothing, they make the sensory judgment from their perceptions induced by stimuli from the physical world such as contact of the clothing or the changes of microclimates between the skin surface and the clothing. With a psychological view, it is essential to understand the relationship between the stimuli and the sensation, and between the sensations and the sensational judgments. Perception is the subjective interpretation of the encoded neural information that is obtained from the physical environment [37].

Wear tests or wearer trials are commonly used to evaluate the garments subjectively. Wearer trial is rated as an end-use performance test to collect the subjective comfort sensations of the wearers [38]. It is a relatively expensive, inconsistent and unsafe but realistic and comprehensive evaluation [2, 39]. Fuzek and Ammons [40] stated that comfort sensation was not only dependent on one objective factor, but also combined with many objective factors including thermal properties (conductivity, specific heat, emissivity), moisture properties (wettability, moisture regain, rate of moisture transfer, heat of moisture absorption), fabric characteristics (construction, hand, stiffness, smoothness), and fiber characteristics (staple length, crimp, diameter, modulus). However, comfort is difficult to measure by objective approaches because the subjective assessment of comfort is in dynamic status but not static. It would be constantly changing as human would become accustomed to different conditions gradually, so wearer trials are also preferable. In addition, wearer trials are rated as an important contribution to the assessment of clothing comfort and the only means by which both subjective and objective measures under the same experimental conditions because many researchers would place the measuring sensors on the human skin to collect the objective data at the same time [41].

Gonzalez and Gagge [42] conducted subjective measurements by wearer trials under a wide range of temperatures and humidities so that it could cover a wide range of absolute sweat rates with different degrees of skin wettedness. It was found that the skin wetness is a good predictor of warm discomfort.

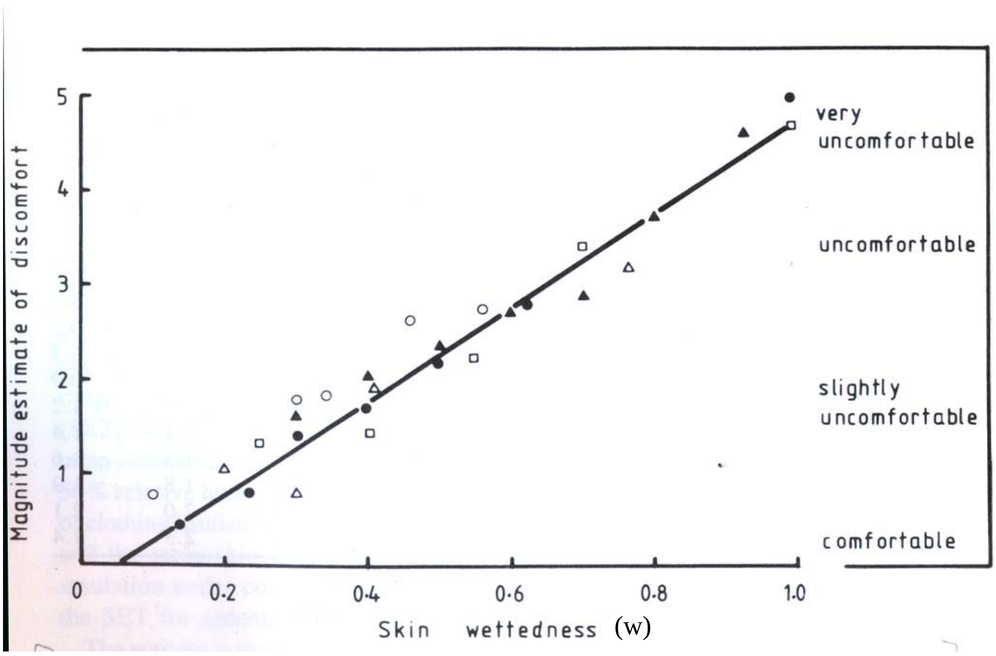


Fig. 2.1 Gonzalez and Gagge [42] found that skin wettedness is a good predictor of warm discomfort.

There are two statistical methods to evaluate the comfort of garments, including the random block design and Scheffe's paired comparison method [40]. For the random block design method, participant is asked to conduct wearer trials of each garment. It is a simple data-collecting method and requires fewer participants, but gives a smaller sampling of the population. On the other hand, for the Scheffe's method, each participant is required to evaluate two garments so that the comfort of garments can be compared directly by participant. However, a large number of participants are involved.

Reliable subjective information is also dependent on accurate selection of participants. Fuzek and Ammons [40] had stated several requirements which are shown below:

- type of the testing garments should be the normal wear of the participants
- participants should have worn the style of the testing garments, excluding innovative garments testing
- participants should not have any technical or professional manner or employed in areas associated with fibers, textiles, etc.
- the participation should be voluntary.

Standardization of the procedures of the wearer trial, kinds and handles of garments is also important to the reliability of the evaluation. Some of important items are recommended in ASTM D3181 [43], which are summarized and listed below:

- Clearly identify the purpose of the measurement, the area of study, the rating scale, the definitions of satisfactory or comfort'
- Define the percentage or scope of unacceptable data which may be unrealistic
- Decide number of wearing and method (s) of refurbishment
- Using a suitable control garment for comparison of performance
- Establish an appropriate experimental design, including considering the time and cost of execution, the potential yield of information from statistical analysis of the results

- Define the number of participants and the exact size of garments required for each
- Standardize the testing garments, e.g. color, style in order to avoid influences of the evaluation by aesthetic differences

2.3 Thermophysiology

Temperature sensitive receptors have been identified in both the skin and hypothalamus. There is also evidence for thermoregulation in the midbrain, medulla oblongata and spinal cord as well as in blood vessels, the abdominal cavity and a number of other sites [44]. The thermoreceptors are either warm or cold types, according to the response to stimuli. In the skin thermoregulators are free nerve endings widely distributed over and within the epidermis [45].

On the other hand, stratum corneum (SC) is the skin region contacted with fabric, which composed of 12 to 15 layers of dead keratinized cells generated by the underlying living dermis. The SC serves as the principal environmental barrier for the body by controlling the passage of water and governing the percutaneous absorption of environmental chemicals. The SC is relatively dry, which its pliability and softness depend on its moisture rather than lipid content. It receives water from the underlying tissues by diffusion and from sweat glands when active. It may absorb water from the external environment and lose water to the environment by evaporation [46].

Vasodilation and Vasoconstriction are the mechanisms of body for controlling the heat loss and retaining the internal body’s heat by varying the flow of blood near the skin. Vasodilation is a thermal function that the skin blood vessels are intensely dilated in order to allow more blood passing near the skin to dissipation heat when the core temperature is above the normal. It results in increase of heat loss from the body to a cooler environment due to the higher skin temperature [24, 47]. If the vasodilation is not enough to bring the core temperature back to normal, the anterior hypothalamus in the thermoregulatory system initiates the sweating process by sending sweat-promoting signals to all of the sweat glands of the body through the sympathetic nerves. Elevating the core temperature by $1^{o}C$ can produce and increase in sweat rate by a factor of 10 – 20 times [16]. For a resting subject, the perspiration can reach to a value in excess of 100 $g/m^2/hr$ under conditions of exertion or a hot environment but his insensible perspiration is about 15 $g/m^2/hr$ under normal conditions [48]. The principal constituent of sweat is water which has a high heat capacity and 2.43 kJ of heat energy can be removed from the body for every gram of sweat evaporated [24]. However, the sweat is not secreted evenly at different regions of the human body. Weiner [49] had conducted a research to observe the regional variation in sweat produced by the human body. It is found that the sweat output differs over the body with roughly 50% from the trunk, 25% from the lower limbs, and 25% form the head and upper limbs.

On the contrary, when the core temperature is below its normal level, the posterior hypothalamic sympathetic centers in the thermoregulatory system cause blood vessels of the skin to constrict due to reduce the flow of warm blood near to the skin surface and diminish the heat loss. Such thermal function is called vasoconstriction [24, 47]. It also contributes to shivering for reducing in skin temperature [39]. Bligh [50] describes shivering as the '… simultaneous asynchronous contraction of the muscle fibres in both the flexor and exterior muscles', i.e. activity producing heat with no net external muscular work. At rest, shivering of a human can increase metabolic heat production from around 70 Wm^{-2} to around 200 Wm^{-2} or more.

Acclimatization would be presented if a person expose to a hot environment for few days because of his physiological change [51]. Internal body temperature and heart rate would be controlled within acceptable limits as heat stress is combated by the increased evaporative heat loss due to increase sweating. Other physiological changes include an increased blood volume and a fall in NaCl content of sweat and urine, so it is found that human tends to adapt under hot environment after few days of acclimatization.

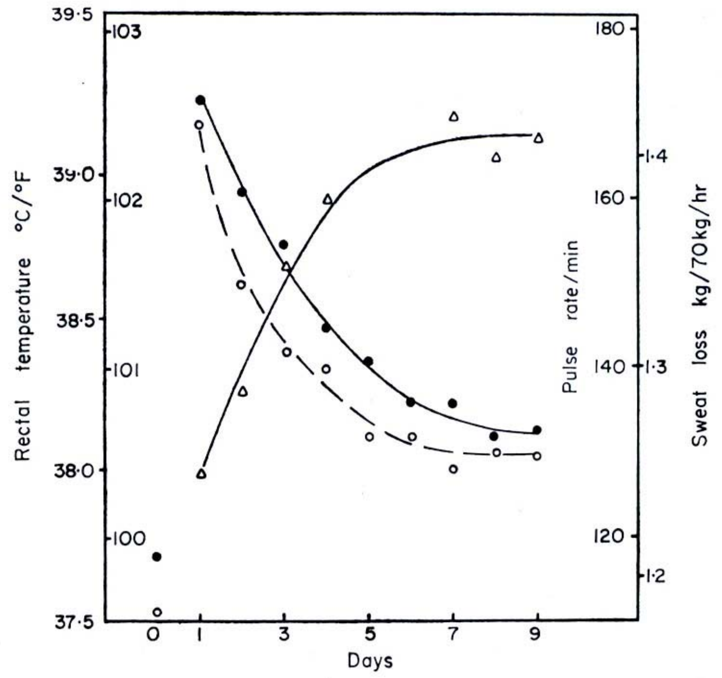


Fig. 2.2 Typical average rectal temperatures (•), pulse rates (◦) and sweat losses (△) of a group of men during the development of acclimatization to heat [51].

Beneath the epidermis lies the dermis where the capillary blood vessels are located. The blood enters the skin by way of multiple arteries that penetrate the deep cutis and then form a loose network parallel to the skin surface. The arteries branch and run perpendicular to the skin surface as they rise through the dermis. Hairpin capillary loops result in the dermal papillae, just beneath the epidermis. The density of the capillary loops ranges from 20 to 50 per mm depending on the body surface location. The amount of heat that can be dissipated from the body core is determined by the rate of blood flow to the skin, which may vary two hundred fold depending on the core temperature. Successful healing of the skin, whether to a burn or minor abrasion, depends on an adequate supply of blood to the microcirculatory capillary vessels [46].

The heat which is generated and which must be dissipated by the body varies from a minimum of about 30 watt/m^2 when lying at rest to a maximum of about 600 watt/m^2 or more during extreme physical activity [3].

For sweating, there are two types of sweat gland: apocrine glands are found in the armpits and pubic regions and are responsible for the distinctive odour in these areas; ecrine are distributed about the body including forehead, neck, trunk, back of forearm, hand and thighs and are responsible for performing the thermoregulatory function [39].

2.4 Heat and moisture transfer through clothing

2.4.1 Basic theory

Parsons [39] stated that the thermal performance of clothing was dependent on dry thermal insulation, transfer of moisture and vapour through clothing (e.g. sweat, rain), heat exchange with clothing, compression (e.g. caused by high wind), pumping effects (e.g. caused by body movement), air penetration (e.g. through fabrics, vents and openings), subject posture and so on.

One of important functions of clothing is to assist human body to maintain a thermal balance between the metabolic heat which it generated and lost to the environment through the heat transfer by conduction, convection, radiation and evaporation [3 - 7].

In fact, the total heat loss of a body is equal to the sum of its dry heat loss and latent heat loss by moisture transmission. The dry heat loss from the body (convection, radiation, conduction) takes place from the skin surface through the clothing to the clothing surface and is dependent on the temperature difference between the skin surface and the environment. Heat is also dissipated rapidly by evaporation of moisture which is transformed from liquid sweat from the skin surface and driven by the difference in partial water vapor pressure between the skin surface and the environment [47].

Conduction

Conduction is the transfer of heat from a hotter to a colder region along a connecting element by the interaction or collision of adjacent molecules [52]. In science view, conduction heat transfer is the flow of kinetic energy from one molecule to the next by direct contact between two [53]. According to the Fourier's law, the energy conduced can be expressed as following:

$$L_{cond} = -kA\ (dT/dl) \qquad (W/m^2) \qquad (2.4)$$

Where k is a proportional coefficient called "thermal conductivity", A is the cross sectional area that thermal energy passes through (same as surface area), dT is the temperature difference, dl is medium length that the thermal energy passes through.

Rate of heat transfer through the clothing is by conduction, which depends on surface area (m^2), temperature gradient (^oC) between the skin and clothing surface and the thermal conductivity ($Wm^{-2}/^oC$) of the clothing [39].

Conduction transfers heat from core organs to the peripheral tissue and to the skin surface and finally to the environment [16].

E.E. Clulow [54] surveyed a literature about the thermal conductivity which textiles had a greater value than the air. That means the textile fibers are much better thermal conductors than the air. Although fibers conduct heat or resist the flow of heat to various degrees, these differences are not significant once the fibers are made into fabric, because a large proportion of space in a fabric is occupied by air that has a substantially lower thermal conductivity than fibers do [13, 17]. That's why the thicker the air layer trapped in the clothing system, the greater is its thermal insulation and its resistance to moisture transmission [55]. Moreover, as there is very small thermal conductivity of still air, the main heat transfer from the outer surface of clothing is by convection and radiation [2].

Radiation

Radiation is defined as the transfer of heat from one object to another object without any contact, mostly in the form of infra-red rays. The emission of the energy may be attributed to changes in the electron configurations of the constituent atoms or molecules [56]. E.E. Clulow [54] also defined radiation as the thermal energy which is transmitted in the form of electromagnetic waves without physical contact between two bodies. In an indoor environment, the nude human body loses about 60% of its heat by radiation [17]. There are two types of radiant heat transmission between man and the environment. The first one is transmitting high temperature by relatively short wavelength radiation such as emitted by the sun. The second is transmitting low temperature by long wavelength radiation, likes emitted by the human body. The energy emitted can be expressed as follows [52]:

$$L_{radir} = \varepsilon\sigma A\,(T_s^4 - T_a^4) \qquad (2.5)$$

Where $\varepsilon <= 1$, is known as thermal emissivity, $\sigma = 5.67 \times 10^{-8}\ W/m^{2o}C^4$ is the Stefan-Boltzmann coefficient. A is the radiative area, Ts is the absolute temperature of the object surface, Ta is the absolute temperature of the ambient.

Considerable radiative heat transfer can occur between the body surface and other objects in environment. If the body surface temperature is higher than environment, the body can loss its radiative heat into clothing materials and environment and by radiation. On the other hand, body can also receive the radiative heat from environment [2].

For clothing, the emissivity and the absorption of radiant heat depends on its color. The effect of clothing colour in absorbing radiant energy is related to the wavelengths of the incoming radiation. Colour has little effect on the emission and absorption of long wavelength radiation, but does affect the emission and absorption of short wave radiation (such as sunlight, UV) with darker colours having the highest emissivity and absorptivity [57].

Convection

Convection is the transfer of heat from one place to another by actual moition of the hot material [17]. Convection of heat transfer can be classified according to the nature of the flow. If the fluid motion is induced by external means such as a pump, a fan, or atmospheric winds, the process is called forced convection. If the fluid motion is caused by buoyancy forces which arise from density differences caused by temperature variations in the fluid, the process is called free or natural convection [52].

Regardless of the particular nature of the convection heat transfer process, we can use Newton's law of cooling to express the convection [56]:

$$L_{conv} = hA(T_s - T_a) \qquad (2.6)$$

Where h is the convective heat transfer coefficient which is dependent on the type of convection (W/m2), A is the surface area, *Ts* is the body skin temperature and Ta is the ambient temperature.

The fibre –entrapped air in a fabric must be at rest or it will transport heat by convection [54]. If the clothing is not skin tight, the amount of natural convection in an air gap between the skin and the under clothing or between different layers of clothing depends upon the thickness of the air gap, the temperature difference between the two surfaces, the area and smoothness of the surfaces and inclination to the horizontal. Natural convection occurs within the air gap when it exceeds about 0.8cm and the surfaces are vertical or the lower surface is hotter than the upper surface [7, 24]. However, the convection would be minimized by trapping a layer of stagnant air between the skin and the environment [16].

Evaporation

However, in a warm climate or under a heavy exercising or working, the dry heat flux by conduction, convection and radiation is not sufficient to balance the metabolic heat production, so the evaporation of sweat at the skin surface is presented [58], which is rated as the primary means of cooling the human body during exercise [59]. Ideally, for comfort, the perspiration evaporates from the surface of the skin and pass as water vapour through the clothing [5].

The rate of water evaporation from the wet skin surface is dependent on the air velocity and skin-clothing-ambient air vapor pressure gradients [60]. The energy by evaporation from skin can be expressed as following [16]:

$$L_{evap} = \lambda \, mA \, (p_s - p_a) \qquad (2.7)$$

Where, λ ,is the heat of evapotaion, m is the permeation coefficient of clothing, A is the surface area, p_s is partial water vapor pressure at skin temperature and p_a is the partial water vapor pressure at ambient temperature.

Examination of physiological literature shows that human can secrete sufficient sweat to remove all metabolic heat generated during sustained exercise provided the sweat is all evaporated. At rest, a body will give off about 60ml of water vapor per hour at ambient conditions. Moderate exertion will increase the amount to 450ml per hour [61]. However, the limitation is not dependent on the amount of sweat secreted but the amount that could be evaporated [62]. Increase of sweat evaporation will lead to increase of the relative humidity of the microclimate with which the clothing is in contact, which can result in discomfort sensation if adequate vapor transmission is not permitted by the clothing [63]. In hot humid environments, high humidity would result in slow sweat evaporation rate [62]. In cold humid environments, condensation of water at points within the clothing may occur depending upon the thermal gradient and the distribution of impedance to water-vapor transfer. The appearance of such condensate in the clothing may result in both impairing its insulative value and imposing an unwelcome burden of further heat demand upon the body [48].

For sweating, it can often cause uncomfortable sensations on skin surface of a clothed human such as prickle and wet-cling [64]. Thus, ideal garment should remove the liquid sweat quickly and allow sweat to pass through or along it to retain comfort [65]. This process can take place in both liquid and vapour states [1].

Mecheels [66] summarized four methods of passing moisture or liquid water through a textile layer:

- Diffusion of water vapor through the air spaces between fibers,
- Absorption/desorption of water vapor by the fibers,
- Migration of liquid water on the fiber surface; and
- Transfer of liquid water through capillary interstices in yarns/fibers.

Water Vapor Diffusion through the air spaces between the material fibers

Water vapor diffusion through the air spaces between the material fibers is the main transport mechanism for water vapor in textiles. There is much less certainty, however, about the important mechanisms under small temperature gradients of ordinary clothing wear. An open fabric structure in a material promotes this diffusion process, but the water vapour transmission through these air spaces is also influenced by the material thickness because the moisture will be trapped in the air spaces or absorbed by the fibers before passing through the fabric if the material is thicker [67].

Absorption/desorption of water vapor by the fibers

The water vapor absorption of fibers depends especially on their chemical structure. The fibers swell after absorbing the water vapor and result in reducing the size of the air spaces, so the diffusion process is delayed. But the water vapor absorbed by the fibers can also be transferred through the fibers and then emitted into the air spaces or released to the environment by desorption. However, this process results in a lower water vapor transmission rate and lower quantity of water vapor for transmission than the diffusion process. Moreover, too much absorbency (such as with thicker fabrics) has a negative aspect in that the fabric becomes heavy and needs to take long period to dry and the wearer may feel cool under a cooler weather [67].

Migration of liquid water on the fiber surface

The effectiveness of the migration process along material fibers is determined by the fibers' wetting capacities and especially by the size of their surface. For the fabric with many microfibers, the fiber surface area is higher, it leads to allow larger amounts of water vapor to migrate [67].

Transfer of liquid water through capillary interstices in yarns/fibers

This process is also called wicking, which is determined by the fiber fineness and is especially common in textile materials made of synthetic fibers [68]. If sweat is transported to the surface by wicking or capillary action, the moisture only evapourates on skin surface mechanically. Wicking or capillary action may occur along the outside of fibers and through the interstices in the fabric [17]. The capillaries in the fabric must form a continuous route from one side of the fabric to the other. Thus, the sweats are drawn away from the skin surface in order to keep it dry as possible. This is achieved through the use of fibres and fabrics which absorb the sweat and then remove it from the skin surface [69]. However, the wetness is invariably perceived and wearer may feel clammy. The fabric would feel cold because the sweat fills the fabric interstices displacing the thermally insulating air pockets, thereby reducing the heat insulating ability [1]. Unless the sweat that is absorbed or wicked into the fabric interstices evaporates the wearer will continue to feel cold.

Spencer-Smith [3] found that the resistance of heat and moisture transfer through the fabrics is much less for damp than for dry fabrics. It is because the capillary spaces between fibres become partly filled with water when the fabric is damp and water can migrate either by creeping along the surface of the fibres when the fabric is wettable or by successive evaporation and condensation between liquid bridges in the capillaries.

When perspiration is presented freely, the T-shirt may become damp but there is no direct flow of water by wicking from the innermost layer of fabric to the next until the former reaches a regain of 70%, even for easily wettable fabrics such as linen and cotton. Once this value has been reached transfer is extremely rapid. For less easily wettable fabric there is much less direct flow of liquid between adjacent layers of clothing [3].

Thus, moisture regain of the materials is important to the thermal comfort of wearer because T-shirt fabrics with better moisture regain property can absorb moisture or sweat. Moisture regain is defined as the amount of moisture in a material determined under prescribed conditions and expressed as a percentage of the mass of the moisture free material or the amount of water resorbed by a dried material at specified equilibrium conditions of temperature and humidity, compared to the mass of the dried material [70]. For selecting materials with better moisture regain and absorption properties, lots of researchers [26, 71 - 78] stated that 100% cotton, or cotton-rich blends were more comfortable to wear and more effective to absorb water vapour and perspiration from skin than synthetic fibres. According to ASTM D1909 [79], the moisture regain values for specified fibres are shown in Table 2.2.

Table 2.2 Moisture Regain of different kinds of fibre

Fibre	Regain, %
Cotton, dyed yarn	8.0
Cotton, Mercerized yarn	8.5
Nylon	4.5
Polyester	0.4

However, the absorbed moisture in hydrophilic textiles like cotton could be a boundary against effective moisture transfer and be released slowly into the surrounding air [80].

It was also found that a certain amount of heat would be liberated when the fibre absorbs moisture [81]. It results in a rise of the temperature of the air space surrounding the skin after high degree of water absorption [82]. As the amount of uptake of water vapor of certain hydrophilic fabrics such as cotton is higher than the hydrophobic fabrics such as polyester, the surface temperature of cotton is higher than the polyester during exercise accompanied by sweating. However, cotton has the ability to decrease its thermal insulation efficiently by absorbing moisture and accelerate dry heat loss through clothing to surrounding air. It leads to reduce the sweating rates of the wearer [74].

Grayson [83] explained that cotton is a vegetable fibre which consists mainly of natural cellulose and keratin with a thin coating of wax. During finishing, this wax coating will be removed, so the cotton fibre can absorb moisture effectively and allows it to evapourate easily. However, fibre with higher absorption of sweat can increase the weight of garment, especially wearing this kind of T-shirt to do exercise, and result in undesirable evapourative cooling after exercising [3, 73].

2.4.2 Modelling

As mentioned in 2.3.1, the total rate of heat transfer through the clothing H_t can be equal to the sum of the direct heat loss H_d and the evaporative heat loss H_e [62], which can be expressed mathematically as:

$$H_t = H_d + H_e \quad (2.8)$$

As Woodcock [62] assumed that H_d and H_e are independent of each other and can be measured independently.

The heat loss from the skin to the environment through dry clothing can be expressed by:

$$H_d = (T_s - T_a) / I_{cl} \quad (2.9)$$

Where T_s = skin temperature, T_a = ambient temperature and I_{cl} = insulation

The evaporative heat transfer H_e can be expressed by:

$$H_e = (p_s - p_a)/ E \quad (2.10)$$

Where p_s = water vapor pressure at skin boundary,

p_a = water vapor pressure of the environmental air,

E = the resistance to evaporative heat transfer per unit of vapor pressure difference across clothing plus overlying air layer.

Thus

$$H_t = (T_s - T_a) / I + (p_s - p_a)/ E \quad (2.11)$$

As mentioned, the heat is predominantly transferred by convection and radiation because of very small thermal conductivity of still air, so the thermal insulation of the surface still air layer, I_{oa}, can be calculated by the following equation: [84]

$$I_{oa} = 1/ (h_r + h_c) \quad (2.12)$$

Where h_r is the radiative coefficient h_r, h_c is the convective coefficient.

In 1972, Kerslake [85] developed a model to calculate the convective heat transfer coefficient accurately.

$$H_c = 8.3 \sqrt{(V_0 + V_{wind})} \quad (2.13)$$

Where V_0 is the lower limit related to natural convection, m/s

And V_{wind} is the wind velocity, m/s and should be more than 0.2 m/s.

In 1977, Mochida [86] stated that the convective heat transfer coefficient is mainly dependent on the air velocity, which can be expressed as:

$$H_c = A + BV^n \quad (2.14)$$

where A, B and n are constants and vary with different conditions as well as different parts of human body. The range of A, B and n are commonly between 0 – 3.5 (A), 1 – 12.1 (B) and 0.391 – 1 (n). And V stands for air velocity.

However, the convective heat transfer is not only caused by wind, but also caused by body activities such as exercising and walking. So, an equivalent air velocity V_{eff} was introduced by Givoni and Goldman [87] to quantify air motion induced by wind and body activity in 1972. According to ISO 7933 [88], V_{eff} can be calculated by:

$$V_{eff} = V_{wind} + 0.0052\ (M - 58) \quad (2.15)$$

On the other hand, for expressing the resistance to the dry heat flow between the skin and clothing itself, the thermal insulation I_{cl} is the most common parameter [89]. It is expressed in square metre degrees Celsius per watt ($m^2 \cdot {}^oC/W$) or clo (1 clo = 0.155 $m^2 \cdot {}^oC/W$), which is the insulation from the skin to the clothing surface. Clo value was introduced as a common international and recognizable unit to present the total clothing insulation in 1941 [90]. One Clo means that the thermal insulation value of an ensemble in which a man wears and feels comfort when sitting in an environment at 20 – 21oC, less 50% R.H. and with wind speed no more than 0.1 m/s, and with the body metabolic rate of around $58W/m^2$.

According to ISO 9920 [89], thermal insulation can be calculated by the following equation:

$$I_{cl} = (\overline{t}_{sk} - \overline{t}_{cl}) / H_d \qquad (2.16)$$

where

H_d *is the dry heat loss per square metre of skin area, in watts per square metre;*

$\overline{t_{sk}}$ *is the mean skin temperature, in degrees Celsius;*

$\overline{t_{cl}}$ *is the mean surface temperature of the clothed person, in degrees Celsius.*

For clothing ensemble, the thermal insulation can be calculated by:

$$I_{cl} = 0.095 \times 10^{-2} A_{cov} \ \mathrm{m^2cw^{-1}} \qquad (2.17)$$

$$I_{cl} = \Sigma I_{clu,I} \qquad (2.18)$$

However, clothing weight alone is not an accurate predictor of clothing insulation. In 1983, McCullough et al. [91] used a manikin to measure the insulation values of different kinds of garments with different weights. It was found that the clothing insulation was less dependent on the weight and the fabric types.

The most accurate equation for estimating individual garment insulation was based on fabric thickness and the amount of body surface area covered by the garment [92]:

$$I_{cl} = (0.00790 \times BSAC) + (0.00131 \times Fab\ Thickness \times BSAC) - 0.0745 \qquad (2.19)$$

Where I_{cl} = clothing insulation (clo)

BSAC = the percent of body surface area covered by clothing

Fab Thickness = fabric thickness

For the water vapor transmission, Woodcock [62] proposed that the moisture permeability index, i_m, could be expressed as follow:

$$i_m = (k_e/k_s) / (h_e/h_c) \qquad (2.20)$$

where k_e is the thermal conductivity of water vapor ($Wm^{-2}\ kPa^{-1}$), k_s is the thermal conductivity of sensible heat ($Wm^{-2o}C$), h_e is evaporative heat transfer coefficient ($Wm^{-2}\ K^{-1}$) and h_c is convective heat transfer coefficient ($Wm^{-2}\ K^{-1}$).

or it could be expressed in the Equation 2.19.

$$i_m = I_{cl} / 2.2\ I_{ecl} \qquad (2.21)$$

where h_e/h_c is 2.2 by Lewis relation, I_{cl} is the intrinsic clothing insulation (Clo) and I_{ecl} is the resistance of clothing to the transfer of water vapor ($m^2\ kPa\ W^{-1}$).

2.5 Heat and moisture transfer properties of clothing

There are many heat and moisture transfer properties of clothing which can be evaluated by different objective physical measurements. Thermal insulation and moisture regain are two of the most common thermal properties investigated by the previous researches.

The amount of fiber moisture at a certain temperature and relative temperature is expressed as its moisture regain and moisture content [17]. Moisture regain is calculated as a percentage of the dry weight of the fiber, whereas moisture content is determined as a percentage of conditioned weight. In the case of moisture regain, the fiber or fabric is dried to remove all moisture it may contain. It is then weighed, exposed to a source of moisture, and reweighed. The calculation for moisture regain is calculated by Equation 2.26.

(Wet weight – Dry weight / Dry weight) x 100 = % Moisture Regain *(2.22)*

In the case of moisture content, the fabric or fiber is not dried, its initial weight includes the moisture it may contain. The calculation for moisture content is

(Wet weight – Moist weight / Moist weight) x 100 = % Moisture Content *(2.23)*

2.5.1 Test methods for heat and moisture transfer properties

Methods for measuring heat and moisture comfort of fabrics or garments can be classified into three groups. Wang and Li [93] had compared the advantages and disadvantages of these three groups of testing methods.

Table 2.3 Advantages and Disadvantages of Three Groups of H&M TP Testing Methods.

Group of Testing Methods	Advantages	Disadvantages
Microenvironment Method	Method is feasible, device is easy to operate, experiment period is short and experiment repeatability is good	The result deviates from reality
Thermal Manikin Method	can be used in any environment and error is little	No passion change, so it could not feedback psychological change
Wear Trial Method	Consistent with the reality	Experiment period is very long

The first group measures the heat and moisture transmitting property of fabric. The second group tests the garment's thermal resistance and moisture permeability using thermal manikin. The third one is wear trial method.

Table 2.4 Details of Heat and Moisture Transfer Properties Testing Methods [93 - 96].

Testing methods and instruments		Basic testing variables	Mainly derived indices	Similar indices
Cooling method	Cylinder thermal insulation device, Katathermometer	The cooling time t(t0) with sample wrapped (unwrapped), temperature decrease σT	Thermal insulation index X = (t-t0)/t0 x 100% cooling time index C=t/t0	Thermal retention ratio E = (t-t0)/t0 x 100%
Constant temperature Method	Constant temperature cylinder thermal insulation device, constant temperature hot plate	The thermal diffusion quantity Q(Q0) with sample wrapped (unwrapped) in time span T	Thermal insulation value TIV (Q0-Q)/Q x 100%	Thermal insulation ratio T=(Q0-Q)/Q x 100%
	Thermal manikin	The thermal diffusion quantity Q, thermal manikin skin temperature T, ambient temperature Ta, the area of thermal manikin body surface A	CLO, thermal insulation ratio T	Thermal resistance R
	Plate thermal insulation device	The heat flux quantity Q, the temperature difference between the both sides of sample σ T, area A, thickness L	Thermal resistance R = (σ T · A)/Q thermal protection ratio	T-Ω, tog, static air thickness
Thermal pulse method	JFY-B1 (Tianjin textile university manufactured)	Temperature behavior after pulse heating	CLO, thermal resistance, thermal insulation ratio	
Moisture permeability cup method	Evaporation method, absorption method	The permeated vapor quantity G(G0) with sample wrapped (unwrapped) in time span T, area A	Moisture permeability ratio Fm = (G0 – G)/G0, moisture permeability quantity fm = G/G0	The permeated vapor ratio G/T·A
	Evaporating dish method	Water quantity G=G0 (1-exp(-ct))	Moisture permeability index Im	
Temperature gradient method	R tube method, plate method	The water vapor pressure difference between the both sides of sample σCP, wet fulx density JW area A, thickness	Rw = σ P/JW (denoted by static air thickness)	Wet impedance Rw= σC/JW
Fabric microenvironment device		The temperature difference, moisture difference and the heat and moisture distribution between the both sides of sample, the apparent heat flux quantity Q, the latent heat flux quantity Qw, the total heat flux quantity Qe	Thermal resistance, wet resistance H & M ratio = R/Rw	Total thermal impedance Re = σ T/Q

Sweating thermal manikin		The temperature difference moisture difference and the heat and moisture distribution between the both sides of sample, the apparent heat flux quantity Q, the latent heat flux quantity Qw, the total heat flux quantity Qe	The climate pressure in microenvironment region, the temperature in microenvironment region	

For the third group, it will be described in details in the further section.

The thermal manikin method is introduced and considered as the most useful tool to predict the thermal comfort by evaluating heat and mass transfer of the overall clothing system in a relevant, reliable and accurate way [2]. Holmer [97] stated that the thermal manikin was mainly applied in determination of clothing heat and mass transfer characteristics for the assessment of the impact of thermal environments on the human body. Chen [98] had grouped the development of the thermal manikin into three generations:

Table 2.5 Three Generations of the Development of Thermal Manikin.

Generation	Descriptions	Examples
The first generation	Not walk-able and non-perspiring manikin	Kerslake [99], Fonseca [100] and McCullough et al [101]
The second generation	Walk-able but non-perspiring manikin	Mecheels and Umbach [102], Olesen et al [103] and Hanada [104]
The third generation	Movable and perspiring manikin	“Coppelius” in Finland (Meinander [105]), “SAM” in Switzerland (Mattle [106]) and Walter in Hong Kong (Fan and Chen [98])

An outer water supply system was used in the perspiring thermal manikin "Coppelius" made in Finland in order to simulate sweating of a real person [105]. 187 sweat glands are installed to the whole body and the water would distribute to each gland with different sweating rates by controlling the proportion time of opening of each valve systemically. The amount of moisture evaporation is recorded by calculating the difference between the weight of supplied water and increase of the clothed manikin. The changes of the weights of each item of clothing before and after the measurement are also used to determine the condensation of the moisture.

Another sweating thermal manikin "SAM" was developed in Switzerland [106]. His principle is similar to Coppelius's but had only 125 sweat outlets which were covered by special pads. It could simulate insensible sweating or both vapor and liquid water by controlling the water evaporation with lower sweating rates. On the other hand, it can simulate sensible sweating by supplying water with higher sweating rates.

In 2003, Chen [98] developed the world first perspiring manikin (called "Walter") which was made of mainly flexible materials (water and breathable fabric) instead of materials of copper, aluminum or plastic. It is used to measure two important clothing comfort parameters (thermal insulation and water vapor resistance) of a garment. A water circulation system within the manikin's body, pumps warm water to his extremities so as to achieve a temperature distribution similar to a real person with central temperature as $37^{o}C$. This is analogous to the human body's blood circulation system, which distributes heat generated from the trunk to the head and limbs. Moreover, the skin is moisture permeable, so the perspiration can be simulated as the moisture transmits through the tiny pores on the breathable fabrics and it can ensure the simulation of the perspiration distributes around the body, but the sweating of many latest manikins is controlled and supplied by more than hundred outlets. Comparing with Walter, the perspiration was still concentrated at the vicinity of the outlets.

2.5.2 Relationship among measuring methods

Currently, there are lots of instruments which are used to evaluate fabric property such as moisture transmission. However, few researchers tried to compare and investigate the relationships among them to arrive at a more meaningful conclusion because the techniques and test conditions of them are quite different from each other. Dolhan [107] examined the correlation between two Canadian Standards of water vapor resistance measurements including Canadian General Specifications Board (CGSB) Control Dish Method and DND method developed by Farnworth and himself. Its analysis method was quite simple that evaluated the validation of the measurements by plotting their testing results with the air layer thickness, so that they were compared by considering the approximation to the slope of the regression line. However, it is impossible for investigating the relationships among similar testing methods accurately. Harnett and Mehta [108] were two researchers who had conducted a research to find the correlations between four different wicking tests, including strip, plate, spot and syphon tests. A high correlation coefficient was found between the wickability by strip test and the radius increase of wet region by spot test. They have identical aspects that the sweat can spread quickly in order to aid comfort by disturbing perspiration. However, direct comparisons between these methods are not possible because their parameters are different and they are lack of sufficient reasons to explain the fact that there was no correlation between the other measurements which had the same units. Consequently, no meaningful conclusion was made useful for further research.

Even when the parameters expressed in the same units, the results cannot be compared because the varying water vapour pressure gradients produce large variations in the transmission rate. In 1993, Gibson [109] undertook a detailed correlation between the Sweating Guarded Hot Plate and the ASTM E96 Cup Method of permeable materials, hydrophobic and hydrophilic membrane laminates by standardizing the indices (air resistance and water vapor transmission rate). It stated a clear relationship between these two measurements, excluding the hydrophilic samples. As the test conditions in the hot plate test resulted in a much higher equilibrium water content in the hydrophilic polymer layer, which changed the polymer’s permeability, the air and the water vapor transport rate through the membrane increase. Literature [110, 111] have mentioned how different relative humidity gradients in the various test methods caused intrinsic transport characteristics of hydrophilic polymers to change. Such fabrics may give poor correlations between different test methods that employ differing relative humidity gradients, since the resistance is a function of the water vapour concentration and temperature. Due to this factor, Lomax [112] pointed out the need for wide-ranging correlations for each type of breathable fabric and not just one overall correlation for all fabrics. However, Gretton, Brook, Dyson and Harlock [113] classified the samples into four categories including air permeable fabrics, microporous, hydrophilic and hybrid coated and laminated fabrics. The results of this correlation indicated that hydrophilic and hybrid materials strayed furthest from the trend line. The relationship applying to each individual breathability mechanism group, however, were not examined. Gretton [114] et al. solved this problem by selecting the samples laminated with hydrophilic films with equal thickness and chemical composition only.

Although many researchers faced the same problems of different the water vapor gradients, Indushekar, Awasthi and Gupta [115] conducted a comprehensive research to identify the relationship between two water vapor transmission measurements by considering not only the standardization of the indices, but also various constructional parameters (weight, thickness, porosity, cloth cover and air permeability). It is beneficial to investigate the key factor of the relationship between measurements. Though a moderate relationship between two tests was found due to the effect of difference in water vapor gradient, good relationships were observed between the air permeability and water vapor transmission measured by either one. It suggested that water vapor transmission through the air spaces between the material fibers is the main transport mechanism for the water vapor in textile structures and is dependent on the volume of air trapped in the fabric.

2.6 Recent Developments of Functional Knitted T-shirt Fabrics

T-shirt is traditionally made from cotton in single jersey or interlock knitted structures. However, in recent years, new fabrics have been developed using engineered fibres and special constructions to achieve improved wicking properties, quick drying, lighter weights, improved durability and easy care.

2.6.1 Akwatek Polyester Fabric

Akwatek® polyester fabric is one of performance fabrics which, it is claimed, can transport moisture and assist thermoregulation using an electrochemical principle (ref. to Fig. 2.3 and 2.4). It states that it not only pulls moisture away form the human body much faster than capillary action fabrics, but also creates a vapor barrier in cold temperatures, so it works as a multi-seasonal performance wear. Furthermore, it is also claimed that the chemicals cannot be removed by repeat laundering. The Akwatek® technology modifies the polyester fiber surface at the nano-particle level. With chemical treatment, Akwatek® modifies the chemistry of PET and releases hydrophilic groups at the molecular level. The modified polyester has an active surface layer with anionic end groups that transport water molecules and release them to the atmosphere before they can form into liquid water. Akwatek® is unlike the other capillary action fabrics which require to be worn next to the skin to create humidity, relying on capillary action. If the capillary fabric gaps, the draw is broken and becomes ineffective. With Akwatek®, individual molecules are separated, thus favoring evaporation. Consequently, it is claimed that Akwatek® polyester fabric can enhance human wearing comfort properties. [116, 117]

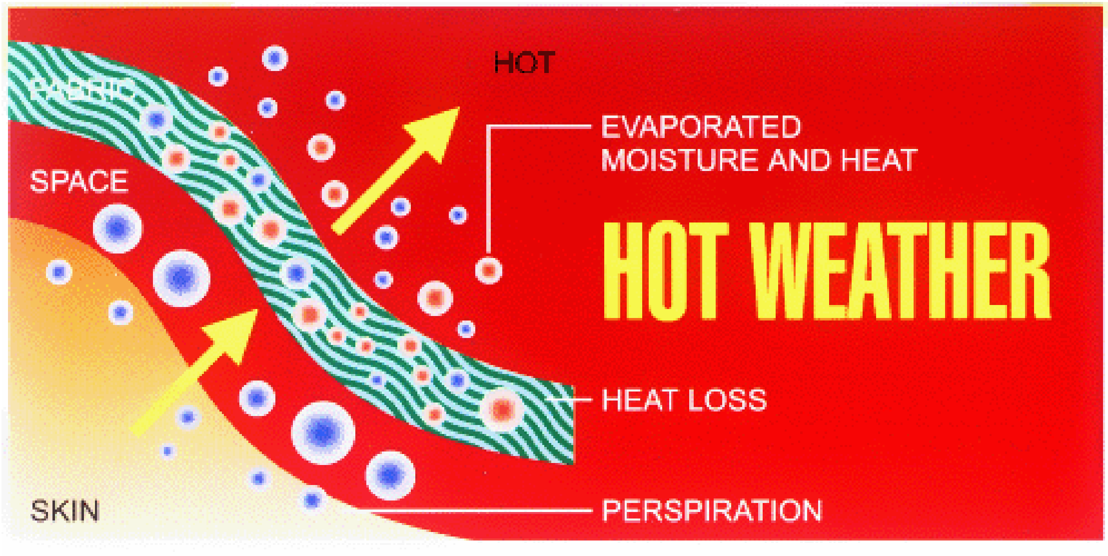


Fig. 2.3 Construction of Akwatek® Polyester Fabric [116].

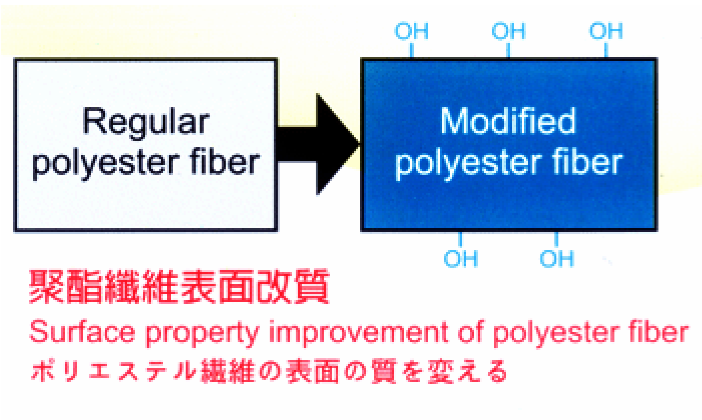


Fig. 2.4 Construction of modifying the polyester fiber of Akwatek® [116].

2.6.2 Coolmax® Fabric

Coolmax® is another functional fabric that offers excellent moisture management properties in any situation (ref. to Fig. 2.5 and 2.6). Fibres in Coolmax® fabric construct as four channels which have a larger surface area in order to transport moisture and heat from the skin to the outer surface rapidly where it can evaporate quickly. At the same time, the uniquely shaped fibers provide great air permeability, even when wet. The air permeability further enhances the thermoregulatory effect to assist staying drier and more comfortable [118,119].

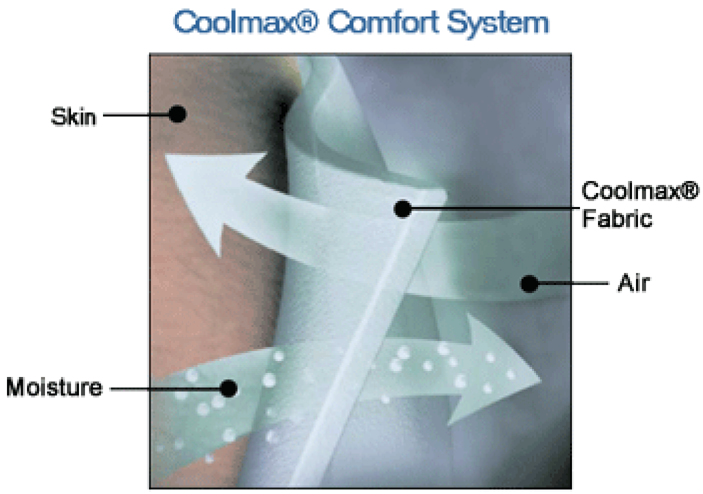


Fig. 2.5 Construction of CoolMax® fabric. [118]

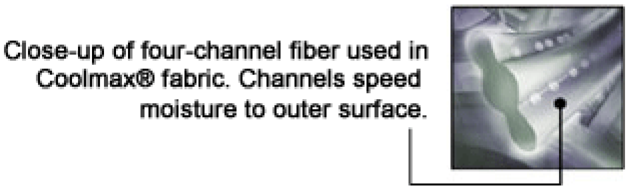


Fig. 2.6 Four-channel fiber system in CoolMax® fabric. [119]

2.6.3 Topcool® Fabric

The TOPCOOL® fiber, a new fiber with structure of micro grooves, is claimed that it has excellent moisture absorption and sweat drain effects without adding any special auxiliary agents during dyeing and processing (shown in Fig. 2.7). Sudden release of moisture and sweat on the skin surface is absorbed, expanded and transmitted through the core of fiber, and then transferred through the fibers to the fabric surface to expand, which is in turn rapidly vaporized, keeping the skin dry, comfortable and cool. Moreover, large gaps between the star-shaped fibers enhance the absorption of moisture and sweats. In this way, it has a body temperature adjusting effect [120].

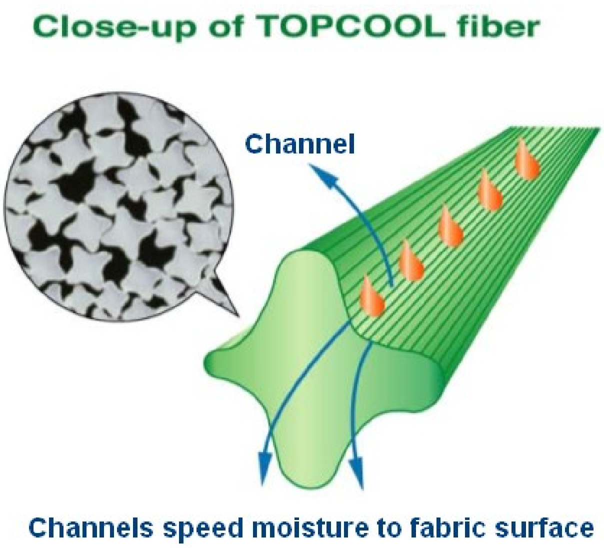


Fig. 2.7 Structure of Topcool® fiber [120]

2.6.4 Tactel® Fabric

Tactel® is a unique two-layered fabric construction designed for high activity sports that brings maximum sensorial and physiological comfort (ref. to Fig. 2.8 and 2.9). The inner TACTEL® layer transfers moisture towards the more absorbent fine filament Tactel® outer layer where it evaporates efficiently. The fabric contains a high number of micro threads which result in efficient moisture management, good body microclimate control and quick drying [121].

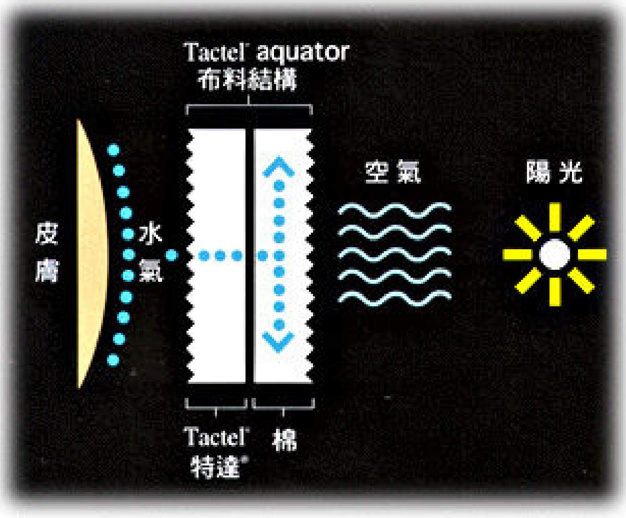


Fig. 2.8 Construction of Tactel® Fabric [121].

Fig. 2.9 Structure of Tactel® Fibre [121].

2.6.5 Nike® Dri-Fit Fabric

Nike® Dri-Fit [122] is a popular inner layer fabric as it is claimed to carry the sweat from the skin to the outside of a T-shirt rapidly (ref. to Fig. 2.10). With mesh structure, it can accelerates the evaporation of sweat and enhance the air circulation to increase heat loss. Good moisture absorbency by the inner layer is also claimed to improve the thermal comfort of the wearer, so it is proposed to wear next to the skin to keep the body dry.

Fig. 2.10 Nike® Dri F.I.T. fabric structure. [122]

2.7 Relationships between comfort sensation, clothing properties and physiological responses

Physiological responses, thermal and moisture transport properties of fabrics and garments and human comfort sensations are closely related. During normal wear, insensible perspiration is continuously generated by the body. Steady-state heat and moisture fluxes are thus produced and gradually dissipated to maintain thermoregulation and result in thermal comfort [123, 124]. In this case, the clothing becomes a part of the steady-state thermoregulatory system. In transient wear conditions, characterized by intermittent pulses of moderate or heavy sweating caused by strenuous activity or climatic conditions, sensible perspiration and liquid sweat occur and are rapidly managed by the clothing. This property is important in terms of sensorial comfort as well as thermoregulation of the wearer [125]. Thus, heat and moisture transfer properties under both steady and transient conditions must be considered for prediction of wearer comfort.

2.7.1 Relationship between comfort sensations and clothing properties

As clothing comfort is a very important topic nowadays, there are many researchers who had conducted researches to investigate the relationship between the thermal properties of clothing and the human comfort perceptions.

Table 2.6 Previous Researches of investigating the relationship between comfort and clothing properties

Years	Researchers	Methods / Objectives of researches	Conclusions / Results
1981	Fuzek, J. F. [8]	- Investigating the relationship between subjective comfort evaluations and different objective factors, including mechanical properties, fitness, thermal and moisture related properties of warm weather wear of T-shirts. - Subjective evaluations were obtained after one time of wearing, after five times of wearing and laundering, and after ten times of wearing and laundering. then fill in the questionnaire.	- According to the t-test results, garment fitness was rated as the main determinant of comfort sensation. Next in important was fiber composition or garment style. However, moisture related properties and thermal transmission properties were not significant to comfort.
1984	DeMartino, R. N., Yoon, H. N. and Buckley, A. [9]	- Using t-test to find the correlation coefficient between the results of in-house laboratory tests (fabric construction parameters, moisture transport, vapor transport and mechanical properties) and subjective wear trial data by wearing cotton and improved polyester garments.	- Insignificant relationship between moisture or vapor transport properties of fabrics and comfort, but some of the mechanical properties such as stiffness and scratchiness were relatively higher correlation coefficients.
1985	Scheurell, D. M., Spivak, S. M. and Hollies, N. R. S. [10]	- Investigate the relationship between dynamic surface wetness of knit sport shirtings and subjective moisture comfort sensations. - moisture level is measured by dynamic surface wetness color index	- A high relationship is found with using different kinds of fabric types and environmental conditions.

1991	Li, Y., Keighley, J. H., McIntyre, J. E. and Hampton, I. F. G. [11]	- conducted a more comprehensive research to find the correlation between clothing properties and comfort sensations by considering more than 10 thermal and mechanical properties by Principal Component Analysis	- Wearing comfort sensations under hot and cold environment were significantly correlated with fabric tensile properties, compression cage recovery rate, surface roughness, compression properties, the drop and demand wettabilities and thermal resistance. - Moreover, the handling feeling was highly dependent on drop and demand wettabilities of fabrics, and fabric tensile slope, fabric friction, bending and compression properties. - Principle Component Analysis was rated as more meaningful as it will combine the properties with higher correlation coefficient before finding another relationship
1999	Lubos, H. [126]	- Comparing the modified PES shirts with the PES/cotton blends and pure cotton - Identify the parameters of thermal comfort	- Modified PES fibres like Coolmax results in improving the thermal comfort in conditions of superficial wetting. - The structure of the fabric containing too many chemical agents deposited inside the fabric may lead to worse comfort feeling in the wet state, in spite of the fact that their steady-state water vapour permeability stays very high. It may be because closing-up the finest capillary channels should reduce the vertical suction height of water in fabrics which should result in worse moisture uptake.
2005	Yoo, S. and Barker, R. L. [12]	- conduct wearer trial of protective clothing - using ANOVA to find the correlation between the fabric thermophysiological and sensorial properties and subjective comfort sensations under different wear conditions which including mild environmental conditions without activity, exercise in mild environmental conditions, hot and humid conditions with and without exercise, and cool down.	- Moisture related properties emerged to be important under hot and humid conditions, and liquid moisture management properties associated with absorption and retention of water by the fabric were influential determinants in the cool down period. - But for the other period or environmental conditions, the comfort sensation was basically dependent on the tactile properties.
2006	Huang, J. and Xu W. [127]	- Investigate the comfort temperature for a clothed body	- Model: $Ta = 27.6 - 5.94 \times I_e$ It shows a state which wearer feel thermal comfortable. That means a person will feel comfortable if he wear 1 clo clothing at 21.5^oC air temperature. - Moreover, 1 clo increase in insulation leads to approximately 6^oC decrease in the air temperature for thermal comfort.

2.7.2 Relationship between comfort sensations and physiological responses

Physiological responses are also predictors of thermal sensations of human. Table 2.7 summarizes the correlative researches.

Table 2.7 Previous Researches of investigating the relationship between comfort and thermoregulation.

Years	Researchers	Methods / Objectives of researches	Conclusions / Results
1953	Andreen, J. H., Gibson, J. W. and Wetmore, O. C. [128]	- Compare the physiological responses and comfort sensations of long sleeves garments with different compositions - Physiological factors include skin temperature, degree of skin wetness, rate of sweating, total sweat cost, and heart rate	- Physiological factors are related to the comfort ratings in a cold environment, but are inconsistent with the clothing comfort in a hot and humid atmosphere because tactile sensation is also very important to the comfort evaluation especially under hot environmental condition as there are differences in the tendency of garments to cling to a body surface wet with perspiration.
1990	Nielsen R. and Endrusick, T. L. [129]	- Evaluate the influence of knit structure of underwear on various subjective sensations of temperature and humidity and the physiological response by wearer trials (running for 40 mins. and taking rest for 20 mins.) and placing sensors. - Find the relationship between the subjective sensations (thermal sensations of body, hand and feet, wetness of body, clothing and the skin and sweating/ shivering feeling)and physiological response (including core temp., body temp., mean skin temperature and skin wettedness)	- all subjective temperature sensations were quite insensitive to knit structure which only influence the thermoregulatory responses at the skin - Core temp. was the main determinant (80-90%) of whole body thermal sensations, but the mean skin temperature was less important determinant in that case. - Skin wettedness was an important factor to the sensations of wetness of clothing and the skin as it may be dependent on the tactile stimulation of the wearer.
2002	Wang, Z., Li, Y. and Kwok, Y. L. [130]	- develop a mathematical simulation of prediction of thermal and moisture sensations by the neurophysiological responses of thermoreceptors	Model: $PSI = \int_0^t Q(y, t)\, dt$ *and* $Q(y, t) = C + K_s T_{sk}(y, t) + K_d (\partial T_{sk}(y, t)/\partial t)$ where PSI = psychological intensity; Q = impulse output response of the thermoreceptors (s^{-1}); K_d = dynamic differential sensitivity, ($^oC^{-1}$); T_{sk} = skin temperature (^oC).

2004	Wong, A. S. W. and Li, Y. [131]	- Investigating the relationship between physiological (skin temperature and humidity) and psychological (thermal and moisture sensations) responses in women's tightly fitting aerobic wear - By t-test statistic method - Analyze data by period and by six locations of body	- A strong linear relationship (R^2=0.96) between skin humidity and subjective moisture sensation at individual locations at a significant level of 0.01. - But the relationship between the temperature and thermal sensation was relatively weaker than humidity and moisture sensation, with average R^2=0.71, and only four selected location's data were significant at the 0.01 level.

2.8 Conclusions

Although many researches attempted to find the correlations between the thermal comfort, physiological responses and clothing properties, the findings tend to vary and sometimes contradict.

2.8.1 Lack of in-depth understanding on the relationship between the thermal comfort sensations and the heat and moisture transport properties of clothing assemblies

Although some researchers had developed the relationship of the comfort sensations with one or few major clothing properties, it is insufficient to evaluate the human comfort perceptions because the psychological sensations may be affected by various types of properties. Limited objective physical factors of fabrics in the relationship is the main problem of research, therefore it is necessary to provide a comprehensive review by considering each relevant property which has potential influence on human comfort sensations. Heat transfer, moisture transmission and sweat absorption are conducetd simultaneously, so some thermal and moisture transport properties may be highly related and can be combined for analysis.

In addition, the thermoregulatory response is important because the comfort perception is dependent on the changes of skin temperature and humidity.

To summarize, comfort rating are better to be analyzed by periods because there is a big difference in physiological responses, so different thermal properties are required to maintain the thermal balance of the body or keep thermal comfort. Furthermore little work was carried out on the performance of functional fabrics, an investigation of such fabrics is essential.

2.8.2 Lack of in-depth understanding of the relationship between the different objective measurements for moisture transport properties of fabrics and garments

Various laboratory tests were used to measure the moisture transport properties. Of clothing. However, their correlations were not known. Some innovative evaluation methods recently developed such as sweating fabric thermal manikin were not compared to the traditional fabric tests yet. It is therefore valuable to conduct research to investigate the relationship between different kinds of objective evaluation methods.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Air permeability, thermal insulation, initial warm/cool feeling, water vapor transmission rate/resistance, wicking level and moisture regain of fabric materials, thermal insulation and water vapor resistance of garment were measured by different kinds of instruments. Also, physiological changes and subjective rating were also monitored during wearer trials. This chapter describes in detail the test methods and experimental procedures used in this project.

3.2 Fabric Samples

Seven interlock and seven single jersey functional T-shirts fabrics were chosen from commercially available samples to be tested in this project. They represent T-shirts that are typically worn by consumers in the environmental conditions being used in the experiment. The details of each sample are shown in Table 3.1 and Appendix A.

Table 3.1 Details of T-shirt samples

Sample	Brands	Compositions	Construction	Color	Thickness (mm)	Mass per unit area (g/m2)
CMsl	CoolMax®	55% 40S/2 Polyester (CoolMax) 45% 40S/2 Combed Cotton Jersey	Single Jersey	Dark Blue	0.6962	199.27
TTsl	Tactel®	62% 40S Combed Cotton 31% Nylon (Tactel) 7% Lycra Jersey	Single Jersey	Dark Blue	0.8318	284.23

AKsl	Akwatek®	100% Polyester	Single Jersey	White	0.644	193.43
NKsl	Nike® Dri-Fit	60% Cotton 40% Polyester	Single Jersey	Dark Blue	0.6266	192
TCsl	TopCool®	44% 40S Combed Cotton 45% 40S Spun Polyester (TopCool) 11% Lycra Jersey	Single Jersey	Dark Blue	0.7036	200.87
93Msl	Meryl® Nylon	93% Meryl® Nylon 7% Spandex	Single Jersey	Blue	0.613	229.7
100Csl	/	100% Cotton	Single Jersey	White	0.556	150.93
CMi	CoolMax®	63% 50S Pima Cotton 37% Polyester (CoolMax) Rib	Interlock	Dark Blue	0.772	148
TTi	Tactel®	59% 40S Combed Cotton 41% Nylon (Tactel) Rib	Interlock	Green	0.9546	184.27
AKi	Akwatek®	100% Polyester	Interlock	White	0.5548	121.83
NKi	Nike® Dri-Fit	100% Polyester	Interlock	Dark Blue	0.6926	128.3
TCi	TopCool®	50% 40S Combed Cotton 50% 30S Spun Polyester (TopCool) Rib	Interlock	Dark Blue	1.071	225.63
89Mi	Meryl® Nylon	89% Merly® Nylon 11% Spandex	Interlock	Dark Blue	0.6212	212.73
100Ci	/	100% Cotton	Interlock	Dark Blue	1.0512	233.3

Besides, objective and subjective measurements of the whole garment are preferable. So, all fabric materials were sewn into garments.

Sample Preparation

1. Before sewing, all fabrics were washed once by industrial washing machine in $30^{o}C$ water.
2. After washing, fabrics were dried hanging in the environment of $20^{o}C$ and 65% R.H.
3. T-shirts are made by the same patterns as the Nike T-shirts in the market.
4. After sewing, dimensions of T-shirts are measured and compared with the Nike T-shirts in order to ensure the dimensions of samples are nearly the same.
5. Conditioned the samples in a controlled environment for at least 24 hours before experiments.

The interlock and single jersey knitted fabrics were sewn into the following two styles:

Interlock	**Single Jersey**
 Fig. 3.1 – Interlock T-shirt sample.	 Fig. 3.2 – Single jersey T-shirt sample.

The figures of all T-shirt samples were shown in Appendix B.

3.3 Objective Evaluation of T-shirts / T-shirt fabrics

All the objective testing methods and experimental procedures used in this project are listed in the following.

3.3.1 ASTM D737-96 Air Permeability Test

Principle

This is a method for measuring the rate of air flow passing perpendicularly through a known area (1 cm^2) of a fabric. It is used to determine how efficient the fabric allows the passage of air through it with 100Pa pressure difference between two fabric surfaces.

Apparatus

Fig. 3.3 Air Permeability Tester

Procedure

The testing condition and procedure of this measurement follows the ASTM D737-96 testing manual.

Calculation and evaluation

Record the air permeability for each specimen and then average the five time readings. The air permeability of individual specimens is expressed in SI units as $cm^3/s/cm^2$. The higher the air permeability value, the more the air passing through the fabric is.

3.3.2 KES-FB7 Thermal Labo II Test

Principle

This instrument is used to evaluate the thermal conductivity of fabrics, the warm/cool feeling when the fabric is in contact with the skin precisely and quickly, and thermal insulation in dry and wet conditions (Simulating sweating or no sweating).

Apparatus

Fig. 3.4 Apparatus of Thermal Labo II

Fig. 3.5 Apparatus of Thermal Labo II

Fig. 3.6 Apparatus of Thermal Labo II

A) Thermal conductivity test

Principle

It is a method for measuring the amount of heat energy transfer from the hotter surface to the cooler surface. For this instrument, water at 20^{o}C circulates inside the Water Box, and the BT-plate and the Guard plate in the BT-Box is pre-set to 30^{o}C and 30.3^{o}C respectively. The heat loss from the BT-box through the test specimen to the Water box in watts is recorded by digital panel meter.

Procedure

The testing condition and procedure of thermal conductivity followed the KES-F7 testing manual.

Calculation and evaluation

The thermal conductivity in Watts/cm· ^{o}C is calculated by

$$k = (W \cdot D) / A \cdot \Delta T_o \quad (3.1)$$

where D = the thickness of samples;

A = area of heat plate of BT-Box (25 cm^2);

ΔT_o = temperature difference between BT-Box and Water Box (10 ^{o}C);

W = the reading on the digital panel meter, which is the heat consumption of the BT-Box.

B) Q-max test

Principle

Q-max test is used to determine the initial contact feeling of fabric. The T- box and Water box are used in this measurement where the BT-box at 30^{o}C supplies heat to the T-box until they have the same temperature with the Water box temperature set to 20^{o}C. The warm/cool feeling is represented by a q-max value (W/m^2K) which is the heat current required per unit area to maintain the condition of a 10^{o}C temperature difference within 1 minute recorded on the digital panel meter.

Procedure

The testing condition and procedure of wam/cool feeling follows the KES-F7 testing manual.

Calculation and evaluation

Average the five readings. The higher q-max value, the cooler the initial touch feeling.

3.3.3 Moisture Transmission Test (Model CS-141)

Principle

This measurement is used to measure the moisture transmission rate of the fabric materials. It is used to determine the rate at which water vapor will permeate fabric at 22°C and 100 % R.H. during an hour period.

Apparatus

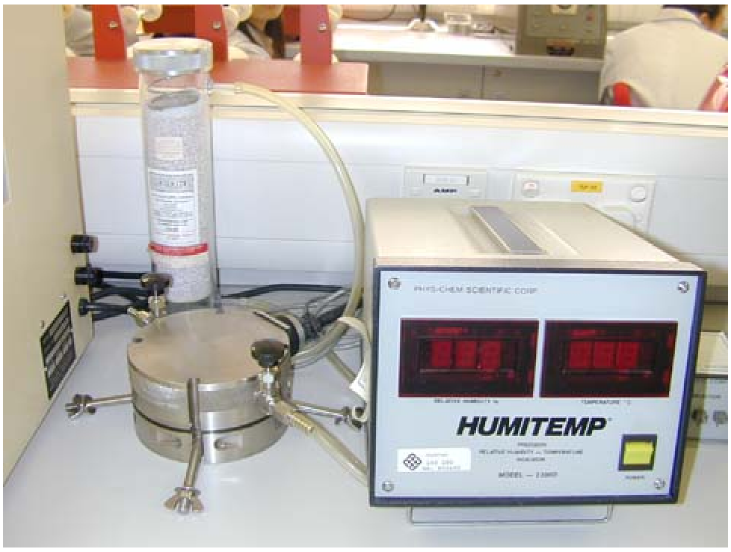


Fig. 3.7 Moisture Transmission Tester (Model CS-141)

Procedure

The testing condition and procedure of moisture vapor transmission rate follows the testing manual of moisture vapor transmission test (model CS-141), but the measurement starts from 50% to 60% of relative humidity values.

Calculation and Evaluation

The moisture vapor transmission is represented by grams per hour per meter square and calculated by:

$$T = (269 \times 10^{-7}) (\Delta\%RH \times 60 / t) (H) /(100 \times 0.0225^{2}) \qquad (3.2)$$

where $\Delta\%RH$ is the average of the differences of Relative Humidity values which are determined from the proper calibration curve and correspond to each dial reading at the actual cell temperature; t is the time between successive readings (3 minutes) and H is the H^2O/m^3 of air at cell temperature (45.74 gms).

3.3.4 Water Vapor Transmission Test

Principle

This method is modified by ASTM E96 Water Vapor Transmission Test which is used for measuring the rate of water vapor movement perpendicularly through a known area (1 m^2) of a fabric to a controlled atmosphere. In this method, a cup contains distilled water which transfers to moisture and then passes through the pores of a fabric to the environment, so the weight of each cup is reduced because of the water loss. The principle of this method is shown in Fig. 3.8.

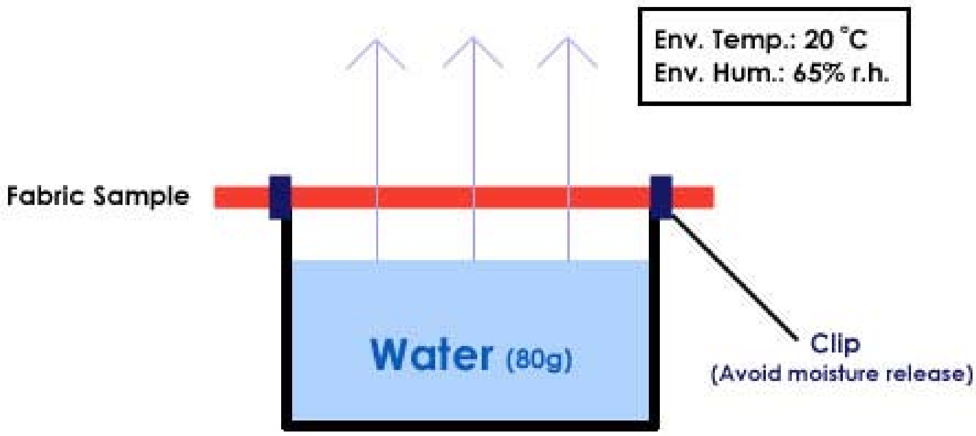


Fig. 3.8 ASTM E96 Water Vapor Transmission Test.

Apparatus

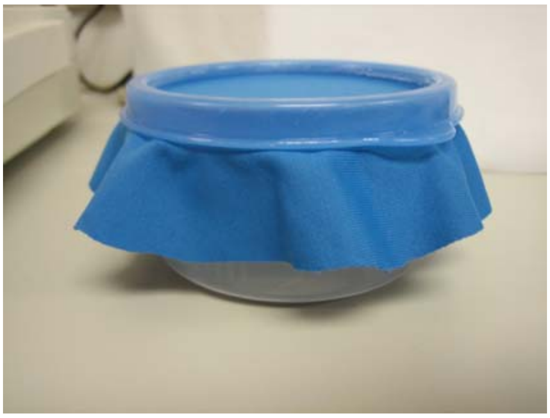


Fig. 3.9 ASTM E96 Water vapor transmission Test.

Procedures

The testing condition and procedure of measuring water vapor transmission rate basically followed the ASTM E96 testing manual. As it is impossible filling the cup with distilled water to a level 19mm from the specimen in our case that would result in making wet of the fabric, it was changed to fill in 80g of distilled water in each cup. Moreover, wax is used to avoid the moisture release in the manual, but it is found that the wax would expand to the surface of the specimen and result in affecting the moisture transmission of the fabric surface, so it was replaced by a clip in order to release moisture of the surrounding.

Calculation and Evaluation

The experiments lasted for 5 days and the weight of each cup is recorded daily. The water vapor transmission rate (WVTR) is represented by grams per hour per meter square, which can be calculated by the following equation:

$$WVTR = G/tA \qquad (3.3)$$

Where G = weight changes, grams;

t = time during which G occurred, hrs,

A = test area, m^2.

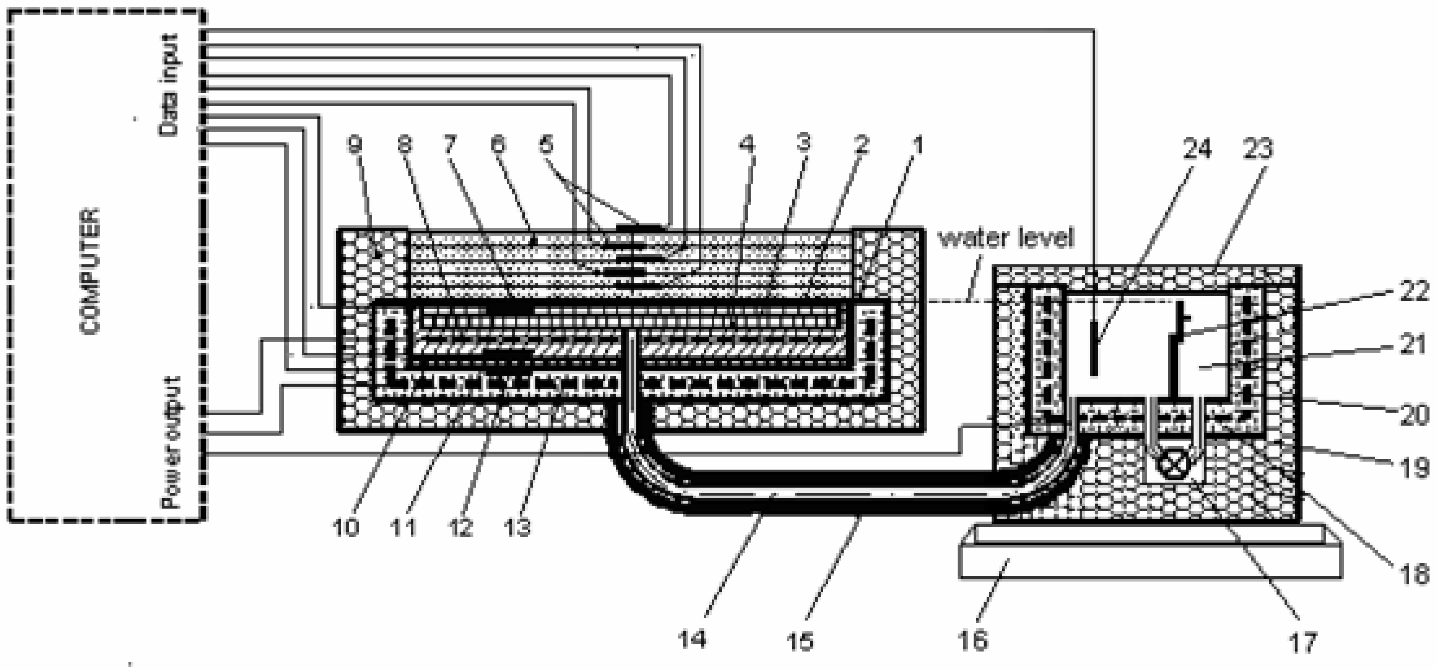
The higher the water vapor transmission rate, the more moisture passing through the fabric to the environment is.

3.3.5 Novel Sweating Guarded Hot Plate Measurement

Principle

This instrument is developed by Fan [132] et al. and it simulates the testing method of ISO 11092. It is used to measure the water vapor resistance that an electrically heated porous plate is covered by a water vapor permeable but liquid water impermeable membrane. The water vapor evaporates and passes through the membrane as vapor and the water vapor pressure difference between two faces of a material divided by the resultant evaporative heat flux per unit area in the direction of the gradient is the determination of water vapor resistance.

Apparatus



1.shallow water container	7.temperature sensor	13.heating element	19.insulation foam
2.manmade skin	8.heating elment	14.water supply pipe	20.heating element
3.porous plate	9.insulation foam	15.insulation layer	21.warm water
4.water	10.insulation pad	16.electronic balance	22.water level adjustor
5.measuring sensor	11.temperature sensor	17.water pump	23.cover
6.layers of specimen	12.temperature sensor	18.water tank	24.temperature sensor

Fig. 3.10 Structure of Sweating Guarded Hot Plate.

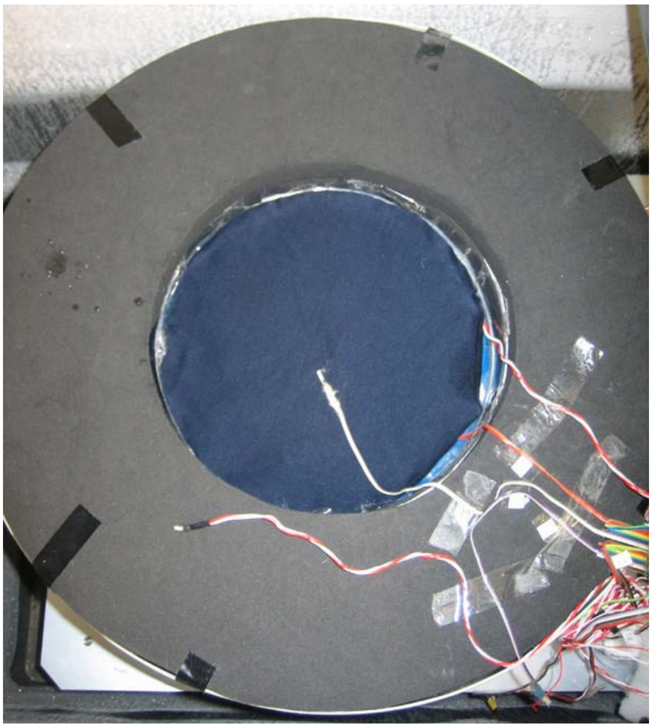


Fig. 3.11 Model of Novel Sweating Guarded Hot Plate.

Procedure

The testing condition and procedure of measuring the sweating guarded hot plate can be referred to the user manual developed by The Hong Kong Polytechnic University or it is similar with ISO 11092.

Calculation and Evaluation

The water vapor resistance is calculated by:

$$Re = (PaHa - PeHe) \cdot A \cdot 133.3 / 0.67Q \qquad (3.4)$$

Where Pa and Ha are the hot plate water pressure (Pa) and humidity (%), Pe and He are the ambient water pressure (Pa) and humidity (%), A is the hot plate area ($0.0444m^2$) and Q is the sweating quantity (g/h).

According to the user manual, 5 layers are put on the hotplate at the beginning and then every layer is taken away every 15 mins. The results of every quantity of layers are calculated into water vapor resistance and are plotted into a graph. The slope represents the actual water vapor resistance of one layer fabric.

3.3.6 Wicking Test

Principle

In this test, a strip of specimen is suspended vertically with its lower edge in a reservoir of distilled water. The efficiency of the wicking action depends on the height of the water of rise in a given time. It is used to determine how well the fabric absorbs the liquid water by capillary action. A clip with 1.15g weight was added to provide a weight to the end of the specimen in order to ensure the specimen is suspended perpendicularly to the water surface. The starting point of the height measurement is when the water line on the fabric is at 2cm apart from the water level of the reservoir and ends at after 5 minutes apart from the starting point.

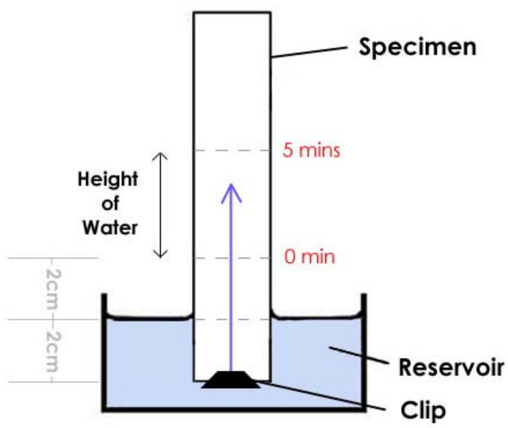


Fig. 3.12 Wicking test.

Apparatus

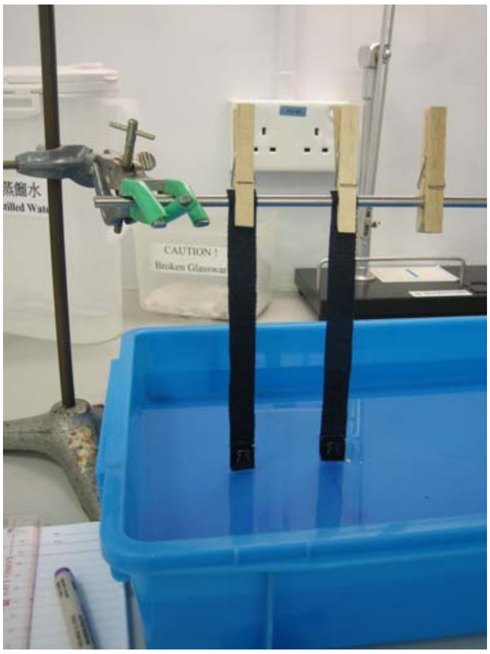


Fig. 3.13 Wicking test.

Procedures

The operational procedure of the wicking test is as follows: [133]

1) Prepare 2 test specimens in warp direction and 2 in weft direction with 1.5cm width and 18cm height and conditioned under standard atmospheric conditions in accordance with Practice D 685 for at least 24 hours.
2) Mark the water level line (2cm apart from the edge) and starting point (2cm apart from the water level line) by water soluble marker.
3) Place the clip at the end of each specimen and hold another end on the stand by another clip.
4) Put the specimen end in the reservoir with distilled water and ensure the water level line is touching the water level.
5) Start the timer when the water line of the fabric arrives at the starting point.
6) Record the height change of the water line after 5 minutes.

Calculations and Evaluations

The height of the water of rise from 0 (2 cm apart from the water) to 5 minutes was recorded. Average the 4 measured heights (2 of warp direction and 2 of weft direction) of rise in 5 minutes for each sample. The taller the height of water rise, the better the capillary action of the fabric.

3.3.7 Moisture Regain Test

Principle

This test method is aimed at determining the moisture content and moisture regain of fabric materials. Moisture content is defined as the amount of moisture in a material determined under prescribed conditions and expressed as a percentage of the mass of the moist material, that is, the original mass comprising the oven-dried substance plus any moisture present. Moisture regain is defined as the amount of moisture in a material determined under prescribed conditions and expressed as a percentage of the mass of the moisture-free material.

Apparatus

Fig. 3.14 Moisture Regain Tester.

Procedure

The testing conditions and procedures are similar to the ASTM D1576 testing manual.

Calculation and Evaluation

The moisture content is calculated as:

$$M_c = [1 - ((W \times D) / (M \times B))] \times 100 \qquad (3.5)$$

The moisture regain is calculated as:

$$M_r = [((M \times B) / (W \times D)) - 1] \times 100 \qquad (3.6)$$

Where M = net mass of subsample at time of sampling,

W = net mass of subsample at time of measurement,

B = net mass of specimen before drying, and

D = oven-dry mass of specimen.

3.3.8 Thermal Manikin - Walter

Principle

The laboratory experiments are carried out in a climatic chamber at 20.0±0.5^{o}C and 65.0±2% r.h. with an air velocity of 0.5±0.3 m/s which simulates various outdoor environments and can be adjusted indoor temperature and moisture values.

A range of clothing products with different thermal properties are prepared for testing by using a sweaty mannequin called Walter who is developed by Prof.

Jintu Fan. The steady static thermal properties of a whole garment are measured, including clothing thermal insulation and evaporative resistance which are two primary parameters of clothing related to thermal comfort.

Apparatus

Fig. 3.15 Sweating Manikin – Walter.

Procedure

The operational procedure of the perspiring fabric manikin is as follows:

1. Put the clothing ensemble to be tested onto the manikin;
2. Start the temperature control and measurement system of the manikin;
3. Wait at least 12 hours for the stabilization of moisture accumulation within clothing;

4. Take measurements of temperature and heat supply if the core temperature varied within ± 0.5°C. The system recorded data in every 40 seconds, and calculates and displays the average of 50 measurements;
5. Add the water level of the manikin to a pre-set level;
6. Wait for one more hour to measure the amount of water required to refill the water up to the original pre-set level. From the amount of refill, we can calculate the perspiration rate.

Repeat Step 4 to 6 at least five times to obtain at least five measurements for calculating average values. The measurement period normally takes about 6 hours.

Calculation and evaluation

Clothing thermal insulation I_t is determined by measuring the heat supply to the manikin, the skin temperature, the ambient temperature, and the perspiration rate of Walter. The total clothing thermal resistance to dry heat transfer (including the clothing surface insulation) is:

$$I_t = A \cdot (T_s - T_a) / L_t \tag{3.7}$$

$$L_t = L - L_e = (L_h + L_p) - L_e \tag{3.8}$$

$$T_s = 0.092T_0 + 0.108T_1 + 0.136T_2 + 0.073\ (T_3 + T_4) + 0.134\ (T_5 + T_6) + 0.125\ (T_7 + T_8) \tag{3.9}$$

$$L_e = \lambda \cdot Q \tag{3.10}$$

where, A is the total surface area of the manikin (A = 1.66m^2), T_s is the mean skin temperature, T_0 is the temperature of the head, T_1 is the temperature of the front, T_2 is the temperature of the back, T_3 is the temperature of the left arm, T_4 is the temperature of the right arm, T_5 is the temperature of the left haunch, T_6 is the temperature of the right haunch, T_7 is the temperature of the left leg, T_8 is the temperature of the right leg, T_a is the mean temperature of the environment, Lt is the dry heat loss from the manikin, L_h is the heat supplied to the manikin or the heat generated by the heaters, L_p is the heat generated by the pump (assuming all energy supplied to the pump is eventually converted to heat, L_p is measured by measuring the power supply to the pump (L_p = 23.5 Watts), and L_e is the evaporative heat loss from the water evaporation, λ is the heat of evaporation of water at the skin temperature (λ = 0.67 Whr/g at 34°C), Q is the perspiration rate or water loss per unit time, which can be measured directly by measuring the amount of water needed to top the water level in the projecting tube back to the original level.

The evaporative resistance R_t can be determined normally by measuring the temperature and humidity at the skin surface as well as the temperature and humidity in the environment, viz.

$$R_t = A \cdot (P_s \cdot H_s - P_a \cdot H_a) / L_e \qquad (3.11)$$

Where P_s is the saturated vapor pressure at the skin temperature, P_a is the saturated vapor pressure at ambient temperature, H_s is the mean relative humidity at the outer surface of the skin, H_a is the relative humidity in ambient.

3.4 Subjective Comfort Sensations and Human Thermoregulatory Responses

To evaluate the subjective perceptions and the direct thermoregulatory responses in wearing different T-shirts, a number of wearer trials were conducted:

■ Wearer Trial and Questionnaire

For investigating the comfort sensations of the ultimate users, wearer trial is a direct way to collect the subjective data. During the wearer trials, wearers are asked to do a series of exercises in a conditioned chamber by wearing the T-shirts with different materials. The subjective evaluation is conducted by rating of their comfort sensation in different periods of time.

Subjects

Four male volunteers participated as human subjects in the wear trial. All subjects were considered healthy and exercised regularly. Each subject tested one T-shirt sample at one time. The details of the four subjects are shown below:

Table 3.2 Details of the human subjects.

Subject	Age	Weight (kg)	Height (cm)	Size of garment worn
A	29	55.4	164	S
B	24	57.2	169	M
C	25	63.7	176	L
D	24	73.2	170	XL

Fig. 3.16 Wearer trial

Procedure

1. A brief instruction is given to the subject in order to ensure that he understands the procedures and the detailed information of the wearer trial.
2. Subjects are not allowed to eat or drink half an hour before wearer trial.
3. Wearers are invited to wash his body with 33^{o}C warm water in a conditioned chamber, and then got used to the environment for 10 minutes by wearing underwear only.
4. The test sample is weighted on a digital balance and recorded on the questionnaire.
5. Wearer is invited to weight on a balance by wearing underwear only.
6. Subject is asked to wear one of testing T-shirts, cotton shorts and cotton socks and to fill in the first section of the questionnaire.

7. A couple of temperature and humidity sensors is placed on the subject's chest, upper back, lower back, hand, shin and calf with adhesive tape.
8. The wearer wears the test sample for running on a running machine for 30 minutes. He is asked to fill in different sections of questionnaire after 5 minutes, 10 minutes, 20 minutes and 30 minutes after exercise.
9. While finishing the exercise, the wearer takes rest in the conditioned chamber for 10 minutes. He fills in the 7th and 8th sections of questionnaire after taking rest for 5 minutes and 10 minutes.
10. Wearer takes off the test sample.
11. The test sample is weighted on a digital balance again and wearer is also weighted with underwear only.
12. Wearer height is measured and he/she fills in the personal information in the questionnaire.

The wearer trials are repeated by wearing different samples.

Conditions of the Chamber

The chamber is controlled as 20^{o}C and 55%R.H.

Running Speed

The speed of the running machine is set as 6.0 km/hr.

Measuring Points

Olesen [134] conducted a comprehensive review on estimating the average skin temperature by analyzing the equations developed by other researchers. In our wearer trials, the measuring points are defined by referring his equation. There are six measuring points which would be placed a couple of temperature and humidity sensors on each position and the wearer should sense the warm/cool feeling and skin wetness of each area. The details are shown as follow:

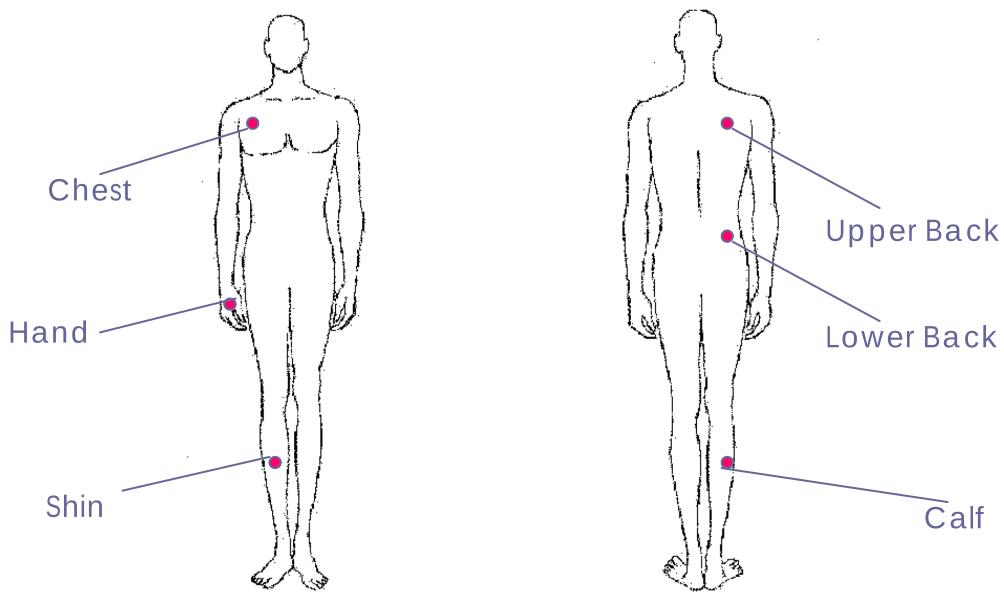


Fig. 3.17 Measuring points of the wearer trials.

The average skin temperature is calculated as:

$$T_s = 0.181\ T_{back} + 0.218\ T_{u.chest} + 0.143\ T_{hand} + 0.150\ T_{l.back} + 0.167\ T_{shin} + 0.142\ T_{calf} \qquad (3.12)$$

The average skin humidity is calculated as:

$$H_s = 0.181\ H_{back} + 0.218\ H_{u.chest} + 0.143\ H_{hand} + 0.150\ H_{l.back} + 0.167\ H_{shin} + 0.142\ H_{calf} \qquad (3.13)$$

Questionnaire Design

There are three questions in each section of questionnaire. The first two questions are used to investigate the warm/cool sensations and skin wetness sensations of different measuring points and the whole body. The last question is about the overall comfort sensation of the human body. The questionnaire is shown in Appendix C.

3.5 Data Analysis for investigating the relationships

The quantitative data of objective measurements and subjective ratings will be analysed by SPSS version 12.0 to study the interrelationship between the heat and moisture transfer properties of clothing using Walter and subjective comfort sensations. Principal Component Analysis was used to investigate the relationship between the factors (combination of different thermal properties) and the comfort sensations. Bivariate Regression was used to find the multiple linear regressions between the objective measurements and comfort sensations. Correlation Coefficient Analysis was used to identify the correlation individually. The details of each analysis are explained in the following sections.

CHAPTER 4

RESULTS AND COMPARISON

OF DIFFERENT FUNCTIONAL FABRICS AND T-SHIRTS

4.1 Introduction

The objective physical properties were measured by different laboratory tests and the subjective comfort sensations and physiological responses were measured by wearer trials. The results are shown below.

4.2 Objective Laboratory Tests

The laboratory testing results of the single jersey and interlock T-shirts fabrics are shown in Table 4.1 and the details of all testing results are shown in Appendix D. The ANOVA Test results of the comparison of the laboratory tests are shown in Appendix E. According to the ANOVA result, there are significant differences between fabrics in terms of different laboratory tests instead of wicking test.

Table 4.1 Laboratory Testing results of T-shirt fabrics

Case Summaries

Sample	Structure		mass per unit area (g/m2)	thickness (mm)	Air Permeability (cm3/s/cm2)	Thermal Insulation (clo)	q-max (W/cm2)	Water Vapor Transmission Rate (g/h/m2)	Wicking Level (cm)	Moisture Regain (%)	Thermal insulation by Watler (m2oC/w)	Water Vapor Resistance by Walter (m2Pa/w)
CoolMax (R)	single jersey	Mean ± SD	199.27 ±5.36	.696 ± .026	94.4±4.7	.000192 ± 4.6E-06	.103 ± 003	20.48 ± .91	6.025 ±0.35	3.71 ± .10	.191 ± 0026	22.10 ± .51
	interlock	Mean ± SD	148.00 ±4.88	.772 ± 036	186.4±7.3	.000205 ± 5.2E-06	.101 ± 002	20.72 ±1.14	4.9 ± .141	4.94 ± .19	.1898 ± .0022	22.44 ± .74
Lactel (R)	single jersey	Mean ± SD	284.23 ±6.01	.832 ± 069	30.6 ± .8	.000181 ± 2.8E-06	.124 ± 002	20.40 ± .85	5.325 ± .035	5.63 ± .21	.1894 ± .0013	22.58 ± .26
	interlock	Mean ± SD	184.27 ±7.29	.955 ± 048	153.2 ± 10.2	.000229 ± 5.0E-06	.111 ± 004	20.75 ± .67	6.9 ± .141	5.60 ± 09	.1936 ± .0019	22.17 ± .22
Akwatek (R)	single jersey	Mean ± SD	193.43 ±4.97	.644 ± 034	207.6±3.4	.000195 ± 1.6E-06	.103 ± 001	21.78 ± .88	7.45 ± 2.12	1.15 ± .10	.2196 ±.0025	21.49 ± .35
	interlock	Mean ± SD	121.83 ±7.54	.555 ± 029	242.6±9.1	.00018 ±3.4E-06	.108 ± 003	21.79 ±2.67	10 ±0	1.75 ± .54	.1752 ± .0068	21.44 ± .17
Nike (R) Dri-Fit	single jersey	Mean ± SD	192.00 ±2.39	.627 ± 022	67.2±3.1	.000153 ±1.7E-06	.115 ± 004	21.01 ± .83	6.825 ± .247	4.93 ± .18	.1868 ± .0044	21.47 ± .16
	interlock	Mean ± SD	128.30 ±4.75	.693 ± 019	196.6±5.3	.000214 ± 2.9E-06	.095 ± 001	21.29 ± .72	8.45 ± 2.12	.94 ± .07	.1778 ± .0048	22.58 ± .10
TopCool (R)	single jersey	Mean ± SD	200.87 ±6.85	.704 ± 022	62.0±2.5	.000195 ± 3.2E-06	.106 ± 002	21.15 ±1.11	6.25 ± 3.54	4.03 ± .18	.1814 ± .0051	22.04 ± .48
	interlock	Mean ± SD	225.63 ±8.89	1.071 ± .115	134.0±6.0	.000275 ±5.6E-06	.095 ± 003	19.99 ± .81	5.2 ± 2.83	3.77 ± .08	.179 ± 0058	23.06 ± .39
93% Meryl(R) Nylon	single jersey	Mean ± SD	229.70 ±8.46	.613 ± 023	58.4±6.8	.000141 ± 2.5E-06	.127 ± 002	19.12 ±1.25	0 ±0	3.18 ± .32	.1714 ± .0024	23.25 ± .11
89% Meryl (R) Nylon	interlock	Mean ± SD	212.73 ±8.91	.621 ± 016	166.4±7.5	.000155 ± 2.5E-06	.127 ± 001	20.04 ±1.09	0 ±0	3.18 ± .18	.1824 ± .0055	21.95 ± .71
100% Cotton	single jersey	Mean ± SD	150.93 ±4.04	.556 ± 014	89.4±12.8	.000144 ± 3.1E-06	.122 ± 003	22.06 ±2.98	0.35 ± 071	6.88 ± .10	.183 ± 0029	21.01 ± .32
	interlock	Mean ± SD	233.30 ±7.09	1.051 ± .102	95.4±3.2	.000218 ± 4.5E-06	.106 ± 000	20.46 ±1.52	0 ±0	7.40 ± 04	.1804 ± .0077	23.41 ± .25

4.2.1 Comparison of Air Permeability of different T-shirt fabrics

From Fig. 4.1, it is obvious that the interlock fabrics had higher air permeability than single jersey knitted fabrics. This may be due to many pores presented on the interlock fabrics, which can allow more air flowing through from insider to the surrounding. Moreover, it’s found that Akwatek® fabric had a higher air permeability value than the others whatever the structure was.

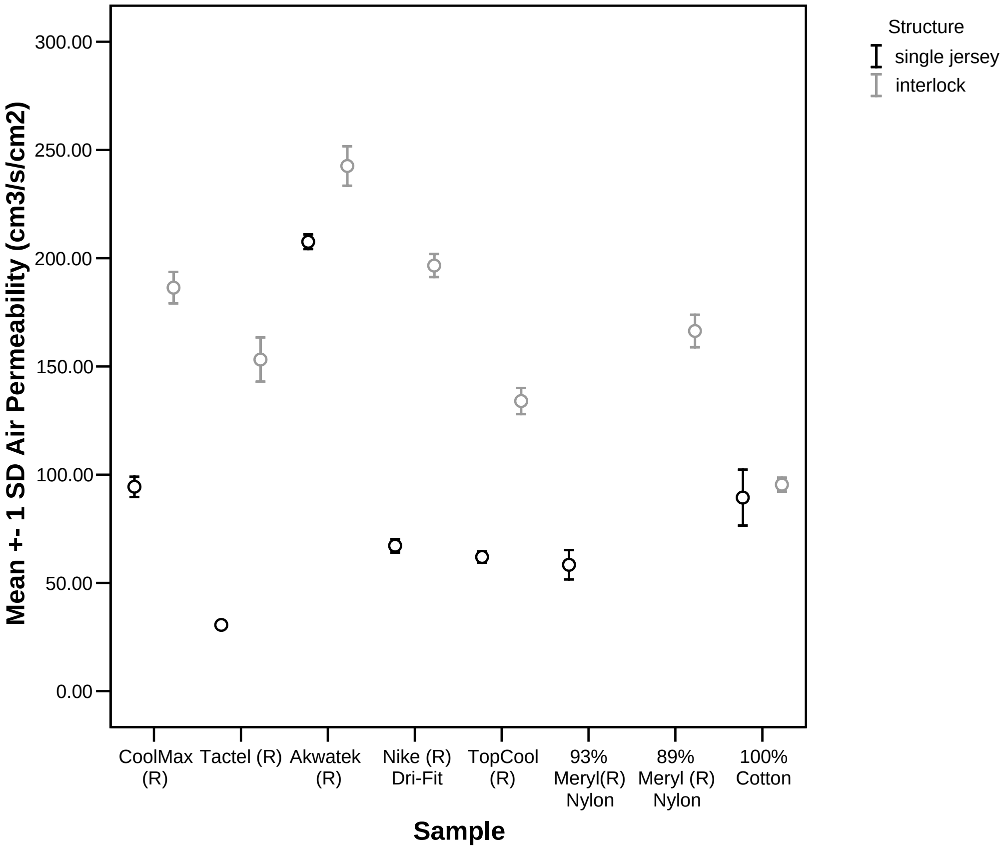


Fig.4.1 Air Permeability of different T-shirt fabrics

4.2.2 Comparison of Thermal Insulation of different T-shirt fabrics

Fig. 4.2 plots the thermal conductivity of different T-shirt fabrics. It showed that 93% Meryl® Nylon fabrics had the lowest thermal insulation value. TopCool ® fabrics tend to have higher thermal conductor, probably due to the fact that it was relatively thicker than the Akwatek® and Meryl® Nylon fabric. The heat was more difficult to release from the inside of a thicker fabric to the environment.

Moreover, interlock knitted fabrics has a higher insulation value than single jersey fabrics. It may be affected by two layers fabrics of interlock knitted fabrics.

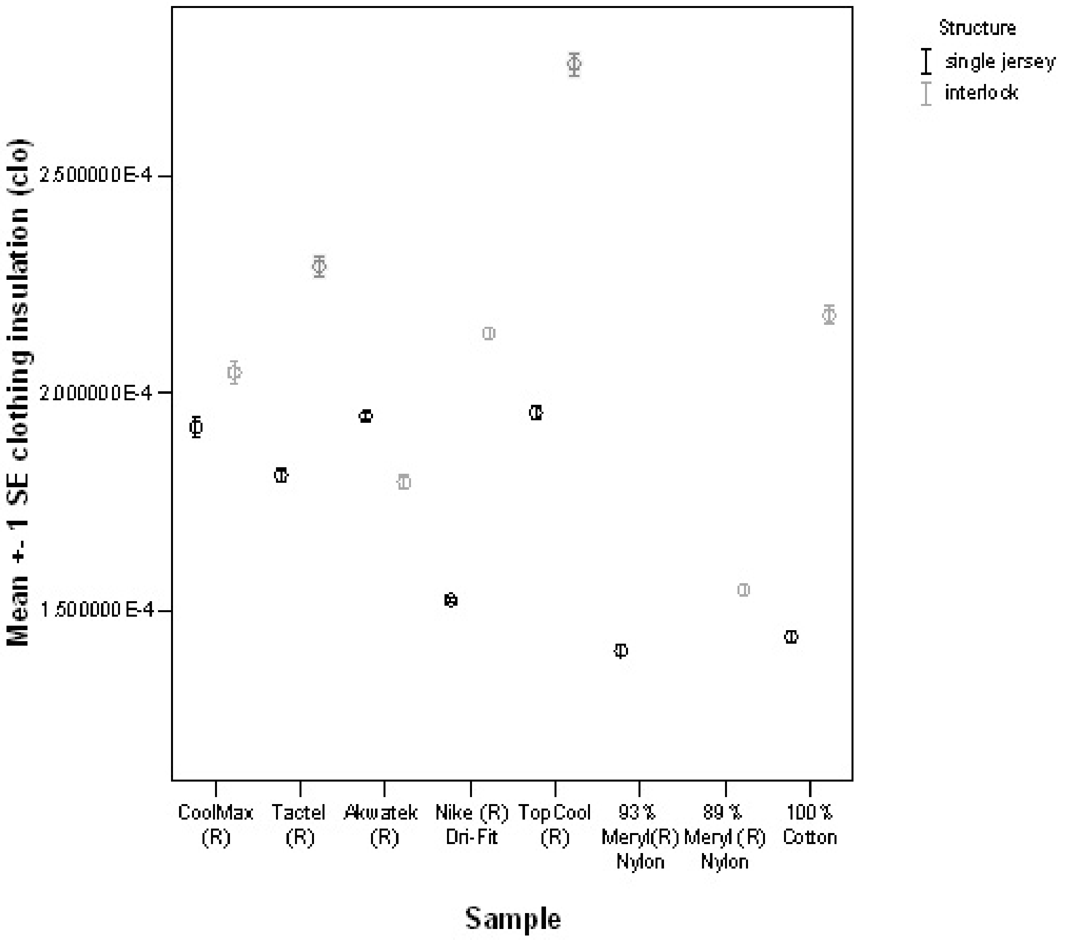


Fig. 4.2 Thermal Insulation of different T-shirt fabrics

4.2.3 Comparison of Q-max value of different T-shirt fabrics

In Fig. 4.3, it plots q-max value of different T-shirt fabrics. The higher q-max value, the cooler the initial touching feeling. Thus, it's found that Meryl® Nylon, 100% Cotton (single jersey) and Tactel (single jersey) fabrics carried the cooler initial feeling to the wearer. The q-max of other functional fabrics may be affected by specific finishing that reduces the surface temperature of the fabrics.

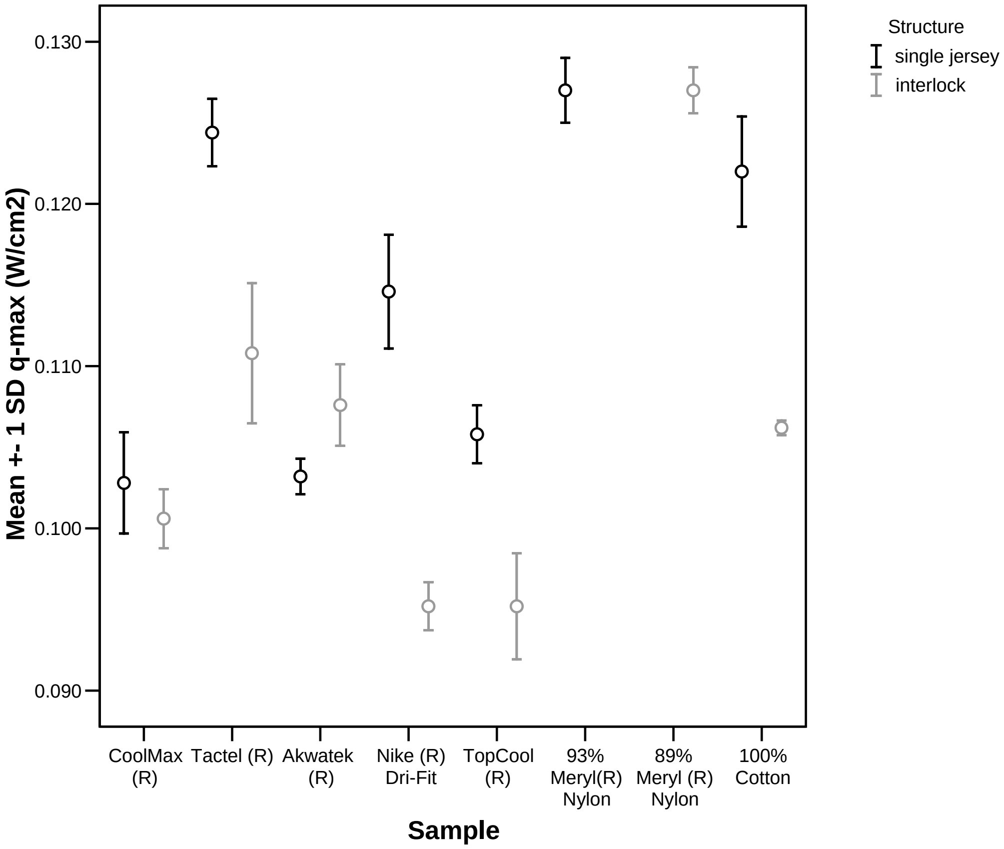


Fig. 4.3 Initial Warm/cool feeling of different T-shirt fabrics

4.2.4 Comparison of Water Vapor Transmission Rate of different T-shirt fabrics

In Fig. 4.4, it shows that 100% Cotton single jersey and Akwatek® T-shirt fabrics transmit the water vapor faster and 93% Meryl® Nylon is the worst in this performance. According to their mass per unit area values, it can be found that the water vapor transmission is higher if the mass per unit area is relatively lower. That means the lower density of the fabric, it can allow more vapor passing through the pores between the yarns, so that the water vapor transmission rate is higher.

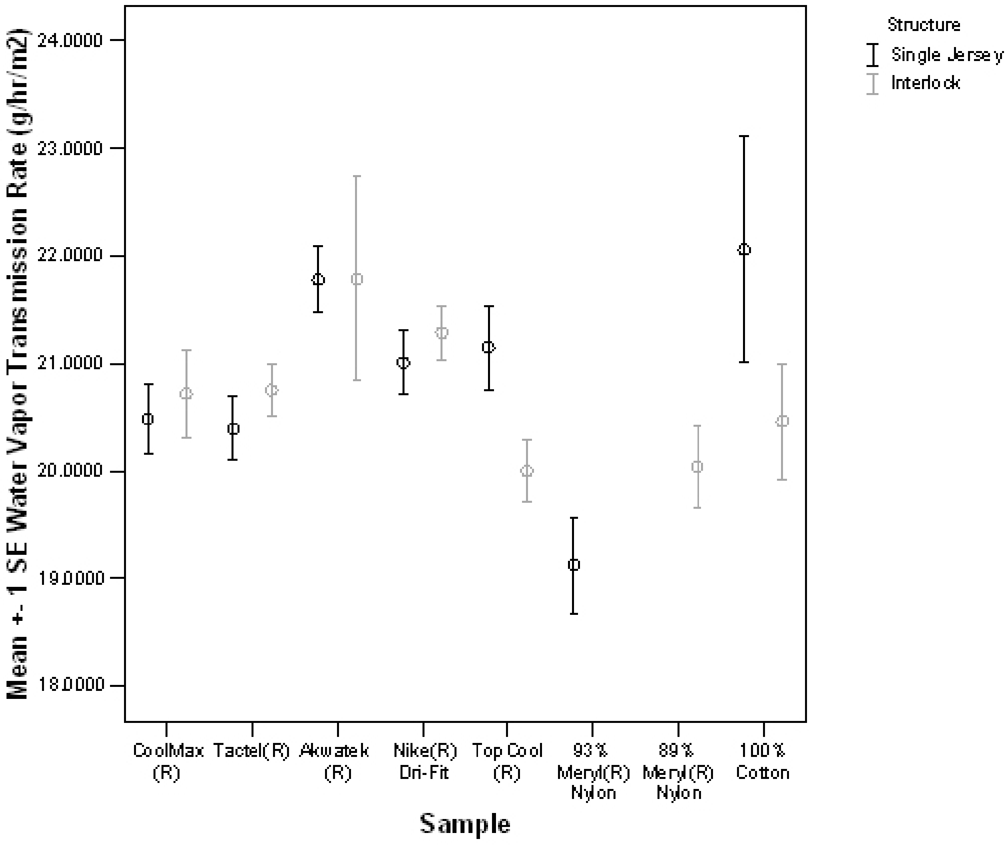


Fig. 4.4 Water Vapor Transmission Rate of different T-shirt fabrics

4.2.5 Comparison of Wicking Level of different T-shirt fabrics

In Fig. 4.5, it is obvious that Meryl® Nylon and 100% Cotton Fabrics have a poorer performance in wicking. It represents that they absorb water or sweat in a relatively slower rate. But for the other fabrics, they have a much better performance in water absorption. It may be because the modified fibre structure and construction increased the fibre's surface area to absorb water more efficiently and effectively.

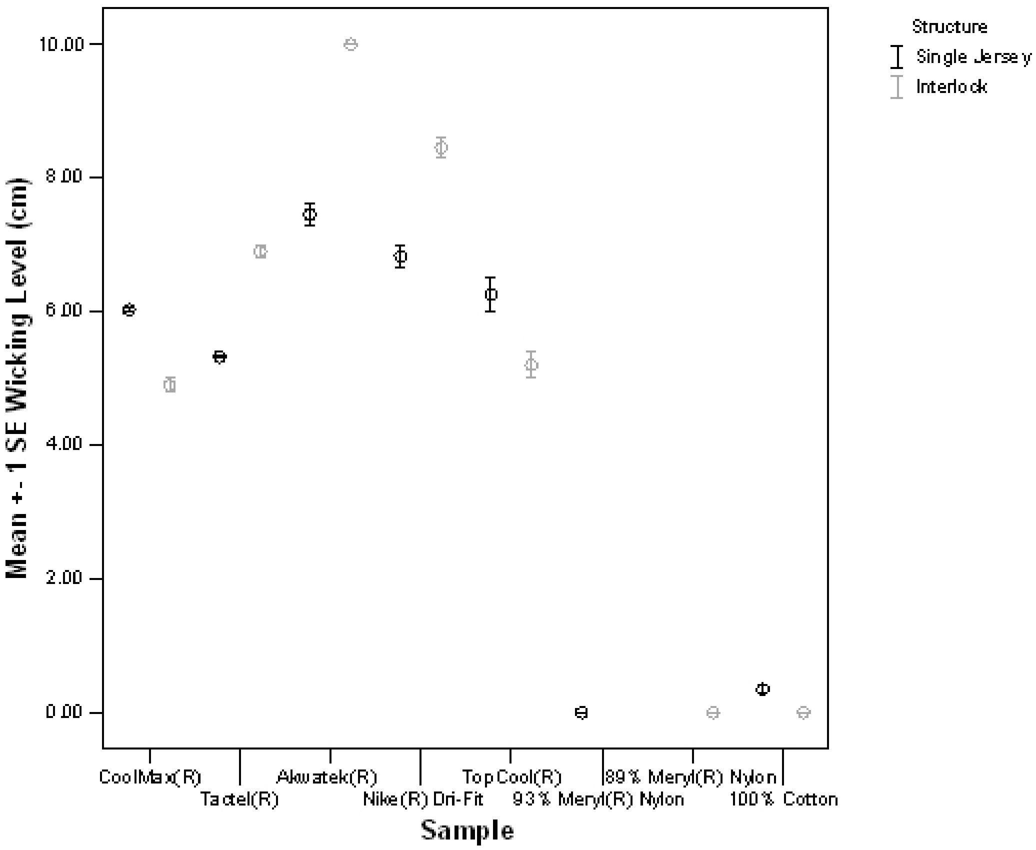


Fig. 4.5 Wicking Level of different T-shirt fabrics

4.2.6 Comparison of Moisture Regain of different T-shirt fabrics

Fig. 4.6 showed the moisture regain of different T-shirt fabrics. It's found that 100% Cotton fabric had the highest moisture regain, that means cotton fabric could consist of a higher amount of water in the material under the conditioned environment. On the other hand, Akwatek® and Nike® Dri-Fit interlock fabrics had the lower moisture regain values, so there were lower amount of water presented in Akwatek® and Nike® Dri-Fit interlock fabrics. It may be dependent on their drying rate of the fabric. As Akwatek® and Nike® Dri-Fit are also functional fabrics with fast drying and water vapor transmission, the moisture within the fibres may release to the environment faster, so it will contain lesser moisture in the fibres.

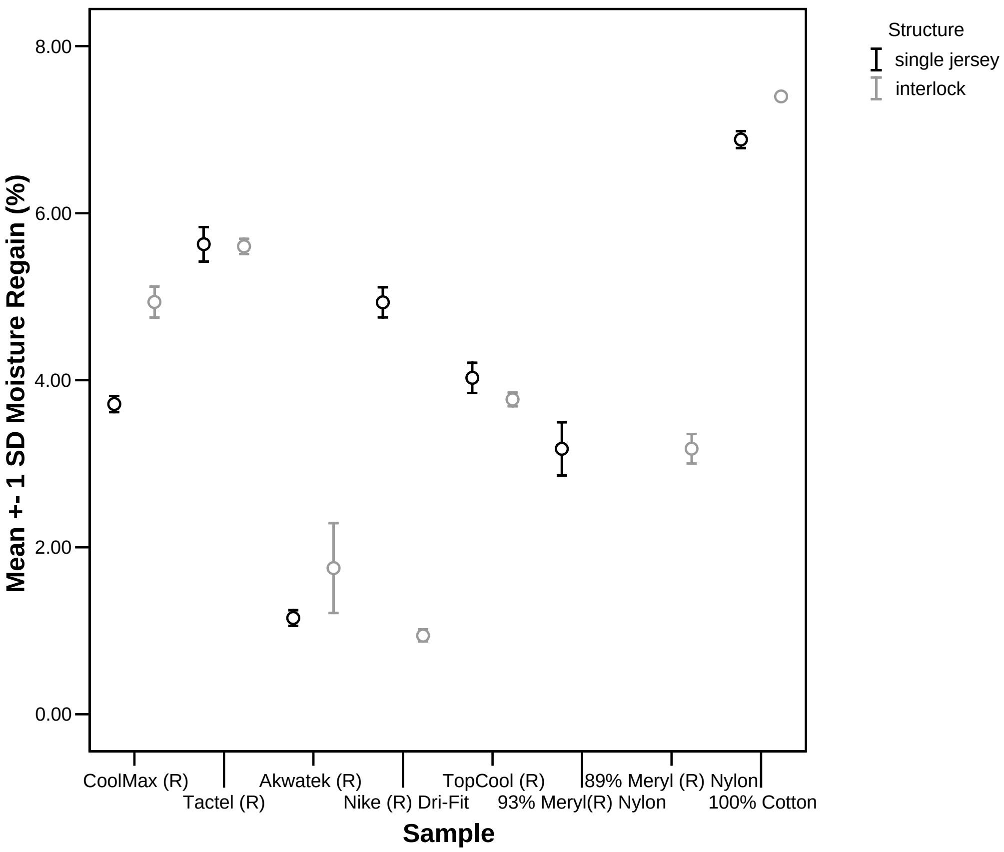


Fig. 4.6 Moisture Regain of different T-shirt fabrics

4.2.7 Comparison of Thermal Insulation of different T-shirts

According to Fig. 4.7, for single jersey knitted fabrics, 93% Meryl® Nylon had the lowest thermal insulation values and Akwatekl® fabric had a higher value of thermal insulation. For interlock knitted fabrics, Akwatek® had also the lowest insulation value and Tactel® had the highest thermal insulation. These results were some difference with that of insulation value measured by Thermo Labo II. It may be because there are more factors affected the heat transfer of a garment.

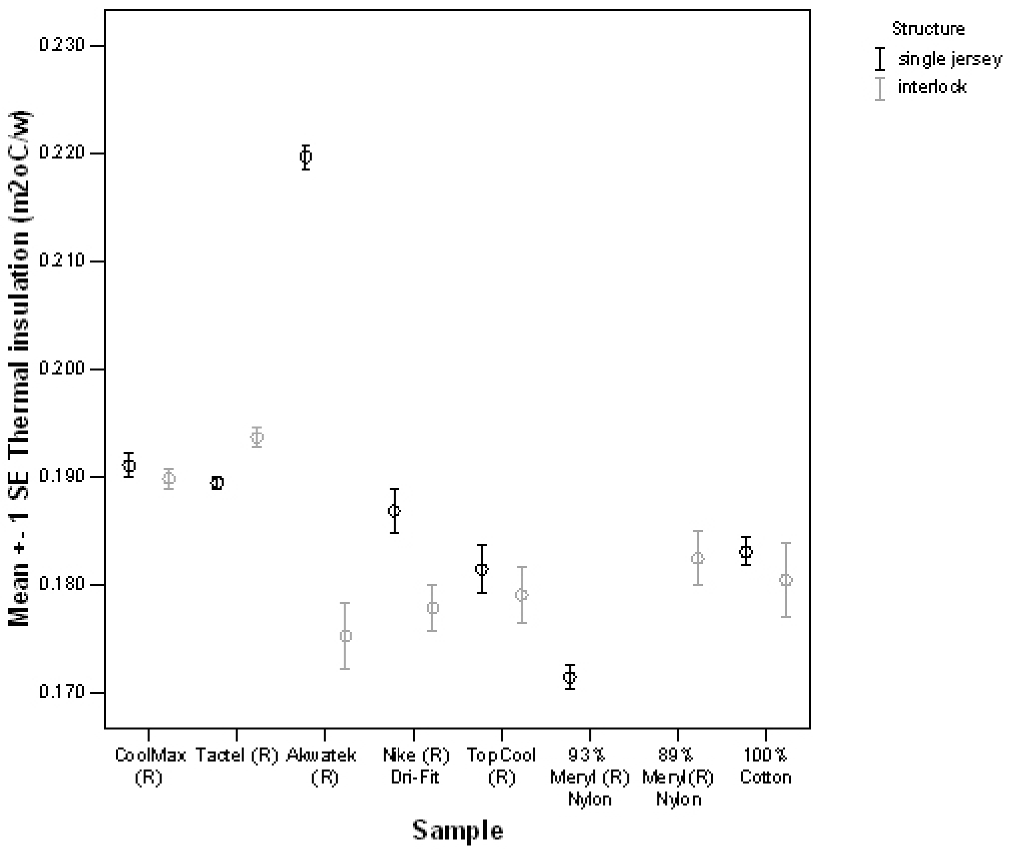


Fig. 4.7 Thermal insulation of different T-shirt fabrics (measured by Walter)

4.2.8 Comparison of Water Vapor Resistance of different T-shirts

In Fig. 4.8, it showed that 93% Meryl® Nylon, TopCool® and 100% Cotton interlock T-shirt had higher resistance of the water vapor transmission. Akwatek®, Nike® Dri-Fit and 100% Cotton had the lowest value of water vapor resistance. As mentioned, it may be dependent on their density of fabric as these fabrics have relatively low value in density (mass per unit area).

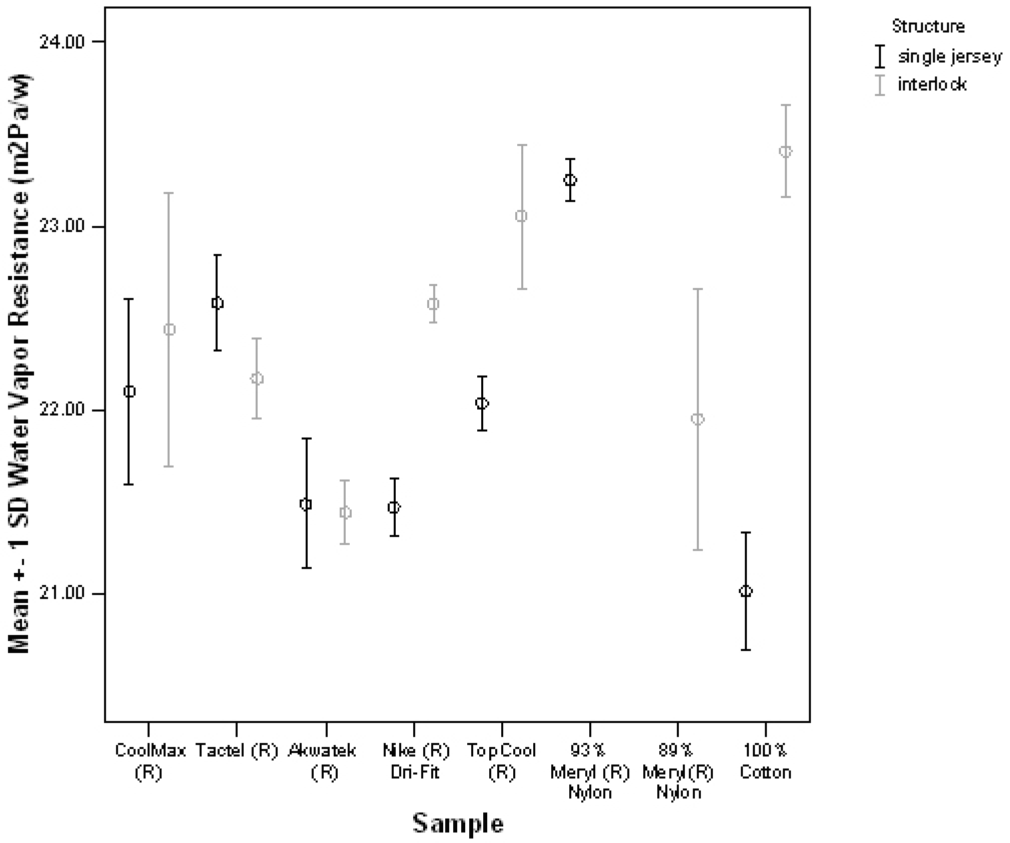


Fig. 4.8 Water Vapor Resistance of different T-shirt fabrics (measured by Walter)

4.2.9 Summary of Testing Results

The summaries of the laboratory testing results of testing samples were listed as follows:

Table 4.2 Summary of the testing results of 7 different single jersey T-shirt fabrics

Ranking in different properties

	1	2	3	4	5	6	7
Weight (G/m2)	100Cs, 150.93	NKs, 192.00	AKs, 193.43	CMs, 199.27	TCs, 200.87	93Ms, 229.70	TTs, 284.23
Thickness (mm)	100Cs, 0.556	NKs, 0.627	93Ms, 0.613	AKs, 0.644	CMs, 0.696	TCs, 0.704	TTs, 0.832
Air Permeability (cm3/s/cm2)	AKs, 207.6	CMs, 94.4	100Cs, 89.4	NKs, 67.2	TCs, 62.0	93Ms, 58.4	TTs, 30.6
Thermal Insulation (clo)	93Ms, 0.000155	100Cs, 0.000144	NKs, 0.000153	TTs, 0.000181	CMs, 0.000192	AKs, 0.000195	TCs, 0.000195
Warm/Cool Feeling (W/cm2)	93Ms, 0.127	TTs, 0.124	100Cs, 0.122	NKs, 0.115	TCs, 0.106	AKs, 0.103	CMs, 0.103
Water Vapor Transmission Rate (g/h/m2)	100Cs, 22.0573	AKs, 21.7832	TCs, 21.1529	NKs, 21.0136	CMs, 20.4828	TTs, 20.3971	93Ms, 19.1241
Wicking Level (cm)	AKs, 7.45	NKs, 6.825	TCs, 6.25	CMs, 6.025	TTs, 5.325	100Cs, 0.35	93Ms, 0
Moisture Regain (%)	100Cs, 6.88	TTs, 5.69	NKs, 4.93	TCs, 4.03	CMs, 3.71	93Ms, 3.18	AKs, 1.15
Thermal Insulation by Walter ($m^{2o}C/W$)	93Ms, 0.171	TCs, 0.181	100Cs, 0.183	NKs, 0.187	TTs, 0.189	CMs, 0.191	AKs, 0.220
Water Vapor Resistance by Walter (m^2Pa/W)	100Cs, 21.01	NKs, 21.47	AKs, 21.49	TCs, 22.04	CMs, 22.10	TTs, 22.58	93Ms, 23.25

Table 4.3 Summary of the testing results of 7 different interlock T-shirt fabrics

Ranking in different properties

	1	2	3	4	5	6	7
Weight (G/m2)	AKi, 121.83	NKi, 128.30	CMi, 148.00	TTi, 184.27	89Mi, 212.73	TCi, 225.63	100Ci, 233.30
Thickness (mm)	AKi, 0.555	89Mi, 0.621	NKi, 0.693	CMi, 0.772	TTi, 0.955	100Ci, 1.051	TCi, 1.071
Air Permeability (cm3/s/cm2)	AKi, 242.6	NKi, 196.6	CMi, 186.4	89Mi, 166.4	TTi, 153.4	TCi, 134.0	100Ci, 95.4
Thermal Insulation (clo)	89Mi, 0.000155	AKi, 0.00018	CMi, 0.000205	NKi, 0.000214	100Ci, 0.000218	TTi, 0.000229	TCi, 0.000275
Warm/Cool Feeling (W/cm2)	89Mi, 0.127	TTi, 0.111	AKi, 0.108	100Ci, 0.106	CMi, 0.101	NKi, 0.095	TCi, 0.095
Water Vapor Transmission Rate (g/h/m2)	AKi, 21.7892	NKi, 21.2861	TTi, 20.7547	CMi, 20.7178	100Ci, 20.4639	89Mi, 20.0412	TCi, 19.9934
Wicking Level (cm)	AKi, 10	NKi, 8.45	TTi, 6.9	TCi, 5.2	CMi, 4.9	100Ci, 0	89Mi, 0
Moisture Regain (%)	100Ci, 7.40	TTi, 5.60	CMi, 4.94	TCi, 3.77	89Mi, 3.18	AKi, 1.75	NKi, 0.94
Thermal Insulation by Walter ($m^{2o}C/W$)	AKi, 0.175	NKi, 0.178	TCi, 0.179	100Ci, 0.180	89Mi, 0.182	CMi, 0.191	TTi, 0.194
Water Vapor Resistance by Walter (m^2Pa/W)	AKi, 21.44	89Mi, 21.95	TTi, 22.17	CMi, 22.44	NKi, 22.58	TCi, 23.06	100Ci, 23.41

4.3 Subjective comfort sensations results

Table 4.4-7 lists out the average subjective sensations of the subjects by wearing different samples in different periods of wearer trials and the details of the subjective testing results were shown in Appendix F. The standard deviation of the subjective sensations was relatively lower at the beginning because skin temperature and humidity changes of the wearers are not significant. It results in more consistent subjective ratings. But there was sudden increase of skin temperature and humidity during exercise for 10-30 minutes and the differences of the thermoregulatory responses of the wearers are relatively higher in this period, so the standard deviation was higher. After exercise, the heat generated by the human body would be eliminated, so the differences of the changes of their thermoregulatory responses could be reduced and it leaded to lower standard deviation than during exercise.

Table4.4 Subjective comfort sensations results of 14 T-shirts at the beginning of exercise

Sample	Structure		Average Warm/Cool Sensation	Average Skin Wetness Sensation	Average Comfort Sensation
CoolMax (R)	single jersey	Mean ± SD	-.0563 ± .3950	-.4875 ± .4077	.5313 ± .8366
	interlock	Mean ± SD	.1438 ± .5192	-.3250 ± .6083	.9750 ± .9573
Tactel (R)	single jersey	Mean ± SD	.1375 ± .1642	-.3937 ± .4213	.2000 ± .8783
	interlock	Mean ± SD	-.1313 ± .2590	-.3687 ± .4728	.5563 ± 1.3170
Akwatek (R)	single jersey	Mean ± SD	-.1250 ± .3359	-.3813 ± .4149	.8375 ± .7896
	interlock	Mean ± SD	-.4375 ± .3193	-.6562 ± .3311	1.6563 ± .3821
Nike (R) Dri-Fit	single jersey	Mean ± SD	-.3688 ± .2975	-.4750 ± .3665	1.5167 ± .2855
	interlock	Mean ± SD	-.1625 ± .3503	-.3438 ± .4500	1.0313 ± .6803
TopCool (R)	single jersey	Mean ± SD	-.2312 ± .3305	-.5063 ± .4452	.7563 ± .6592
	interlock	Mean ± SD	.0125 ± .4470	-.3875 ± .4422	.5000 ± .8594
93% Meryl(R) Nylon	single jersey	Mean ± SD	-.3875 ± .2774	-.4750 ± .2928	1.8000 ± .8084
89% Meryl(R) Nylon	interlock	Mean ± SD	-.5063 ± .3679	-.7688 ± .1534	2.1000 ± .3645
100% Cotton	single jersey	Mean ± SD	-.4750 ± .3105	-.5688 ± .3798	1.2250 ± .7964
	interlock	Mean ± SD	.0188 ± .2235	-.3313 ± .3674	.5625 ± .6891

Table 4.5 Subjective comfort sensations results of 14 T-shirts in the middle of exercise

Sample	Structure		Average Warm/Cool Sensation	Average Skin Wetness Sensation	Average Comfort Sensation
CoolMax (R)	single jersey	Mean ± SD	.7500 ± .4349	.5083 ± .3598	-.0458 ± .6638
	interlock	Mean ± SD	.8625 ± .6582	.6917 ± .5946	.6208 ± 1.0217
Tactel (R)	single jersey	Mean ± SD	.8917 ± .7311	.7458 ± .8030	-.1792 ± .7114
	interlock	Mean ± SD	.8125 ± .4677	.8292 ± .4770	.3625 ± 1.1728
Akwatek (R)	single jersey	Mean ± SD	.7000 ± .6403	.6750 ± .6521	.2458 ± 1.0496
	interlock	Mean ± SD	.3625 ± .4652	.3375 ± .3358	.9667 ± .9509
Nike (R) Dri-Fit	single jersey	Mean ± SD	.5083 ± .6342	.5708 ± .5770	1.0333 ± .4618
	interlock	Mean ± SD	1.0167 ± .6069	1.0542 ± .5574	.2292 ± 1.0771
TopCool (R)	single jersey	Mean ± SD	.7042 ± .8395	.4833 ± .7241	.3583 ± .7856
	interlock	Mean ± SD	1.0000 ± .5564	1.0042 ± .5043	-.2292 ± 1.0024
93% Meryl(R) Nylon	single jersey	Mean ± SD	.5875 ± 1.0458	.5708 ± .9514	1.0292 ± 1.2684
89% Meryl(R) Nylon	interlock	Mean ± SD	.4708 ± .4224	.4792 ± .3702	1.0833 ± 1.1426
100% Cotton	single jersey	Mean ± SD	.4833 ± .7088	.5542 ± .6659	.6458 ± 1.0828
	interlock	Mean ± SD	.9042 ± .6503	.9208 ± .5541	-.1458 ± 1.0515

Table 4.6 Subjective comfort sensations results of 14 T-shirts at the end of exercise

Sample	Structure		Average Warm/Cool Sensation	Average Skin Wetness Sensation	Average Comfort Sensation
CoolMax (R)	single jersey	Mean ± SD	1.2500 ± .8544	1.1750 ± .7354	-.3125 ± 1.0379
	interlock	Mean ± SD	1.1625 ± 1.3462	1.2625 ± .8300	.4625 ± 1.4545
Tactel (R)	single jersey	Mean ± SD	1.2750 ± .9988	1.3875 ± .8702	-.5875 ± 1.0201
	interlock	Mean ± SD	1.5375 ± .7420	1.7625 ± .7465	-.0750 ± 1.6576
Akwatek (R)	single jersey	Mean ± SD	1.3250 ± 1.1332	1.4750 ± 1.0145	.0250 ± 1.4824
	interlock	Mean ± SD	.8250 ± .8292	.7250 ± .5838	.7500 ± 1.1712
Nike (R) Dri-Fit	single jersey	Mean ± SD	1.3250 ± .8837	1.3875 ± .6381	.4750 ± 1.2420
	interlock	Mean ± SD	1.8500 ± 1.0654	1.9125 ± .9578	-.1875 ± 1.8405
TopCool (R)	single jersey	Mean ± SD	1.1500 ± .8010	1.1125 ± .6613	.1625 ± .9767
	interlock	Mean ± SD	1.6125 ± .7465	1.7375 ± .5360	-.5125 ± 1.2822
93% Meryl(R) Nylon	single jersey	Mean ± SD	1.2750 ± 1.3598	1.2750 ± 1.2500	.1625 ± 1.8741
89% Meryl(R) Nylon	interlock	Mean ± SD	.8875 ± .9277	.8125 ± .7353	.7875 ± 1.3835
100% Cotton	single jersey	Mean ± SD	1.2625 ± .9810	1.3000 ± .9600	.4750 ± 1.3105
	interlock	Mean ± SD	1.5375 ± .8280	1.6625 ± .6102	-.6250 ± 1.4615

Table 4.7 Subjective comfort sensations results of 14 T-shirts after exercise

Sample	Structure		Average Warm/Cool Sensation	Average Skin Wetness Sensation	Average Comfort Sensation
CoolMax (R)	single jersey	Mean ± SD	.1125 ± .3543	.2813 ± .2802	.3438 ± .6806
	interlock	Mean ± SD	.1875 ± .3989	.0187 ± .3251	1.0313 ± .9487
Tactel (R)	single jersey	Mean ± SD	.3125 ± .5957	.2625 ± .4883	-.0500 ± .9460
	interlock	Mean ± SD	.3125 ± .5547	.4687 ± .6850	.9688 ± .6892
Akwatek (R)	single jersey	Mean ± SD	.4063 ± .6009	.3125 ± .6312	.4438 ± .9163
	interlock	Mean ± SD	-.2188 ± .4964	-.3625 ± .4104	1.4688 ± .7319
Nike (R) Dri-Fit	single jersey	Mean ± SD	.3000 ± .4964	.3500 ± .4149	.8000 ± .8246
	interlock	Mean ± SD	.3875 ± .6627	.4875 ± .6087	.5813 ± 1.1029
TopCool (R)	single jersey	Mean ± SD	.2813 ± .4899	.0875 ± .3462	.4563 ± .8051
	interlock	Mean ± SD	.3438 ± .4996	.3938 ± .4732	-.0937 ± 1.0975
93% Meryl(R) Nylon	single jersey	Mean ± SD	.4000 ± .6330	.3562 ± .6213	.8750 ± 1.3698
89% Meryl(R) Nylon	interlock	Mean ± SD	-.1500 ± .3964	-.2563 ± .4452	1.0812 ± .9254
100% Cotton	single jersey	Mean ± SD	.1750 ± .5120	.2187 ± .4840	.9438 ± .8654
	interlock	Mean ± SD	.3938 ± .6062	.5250 ± .5542	-.2313 ± 1.1187

4.3.1 Subjective comfort sensations results

Appendix G - J show the comparisons of the subjective comfort sensations of different T-shirts at different periods of wearer trials by ANOVA. At the beginning of exercise, the difference of skin wetness sensations between the testing samples was significant; In the middle of exercise, the differences of both of warmth and skin wetness sensations between the testing T-shirts were significant; At the end of exercise, three kinds of sensations have significant results between the samples; After exercise, results of warmth and overall comfort sensations between the samples were significant.

Warm/Cool Sensations

In Fig. 4.9-12, they plotted the average warmth feeling of 4 subjects by wearing different commercial brands interlock and single jersey T-shirts for exercise at different stages.

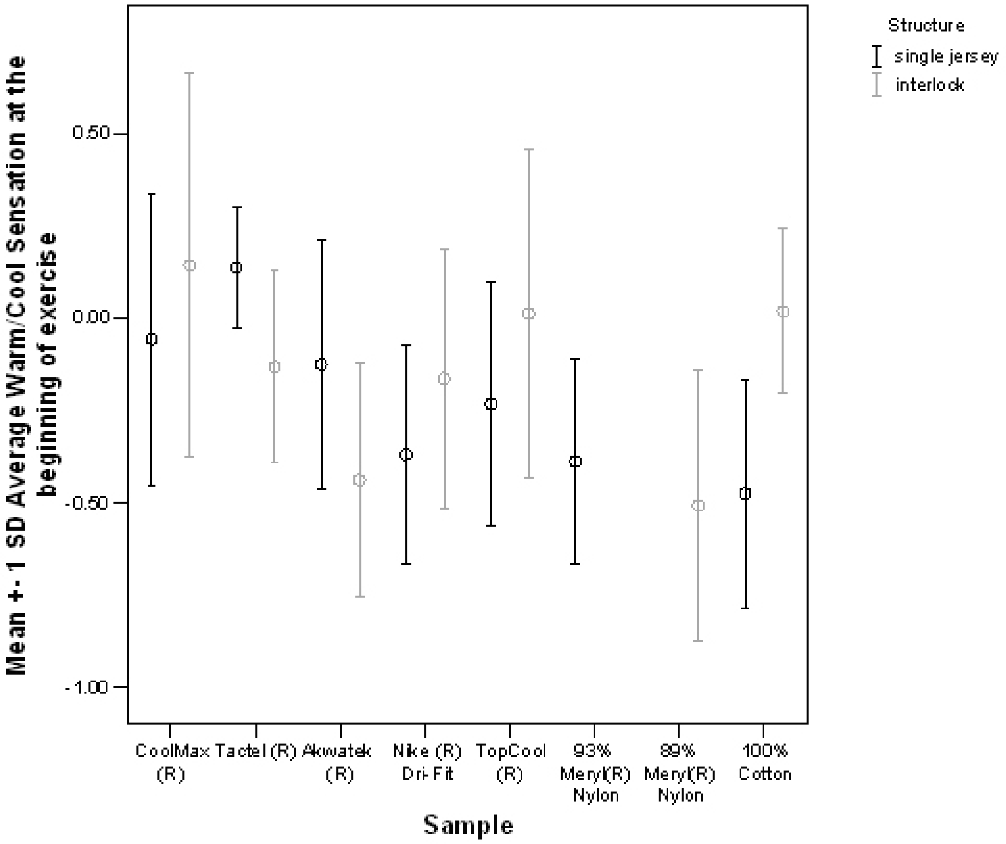


Fig. 4.9 Average warm/cool sensations of 4 subjects by wearing 14 samples at the beginning of exercise

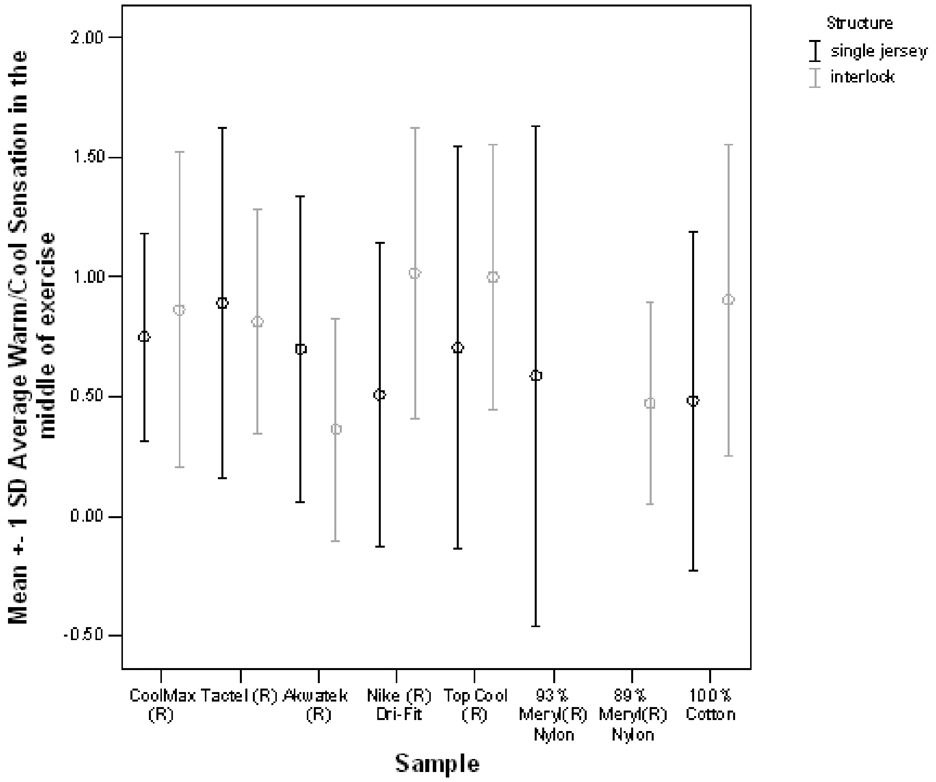


Fig. 4.10 Average warm/cool sensations of 4 subjects by wearing 14 samples in the middle of exercise

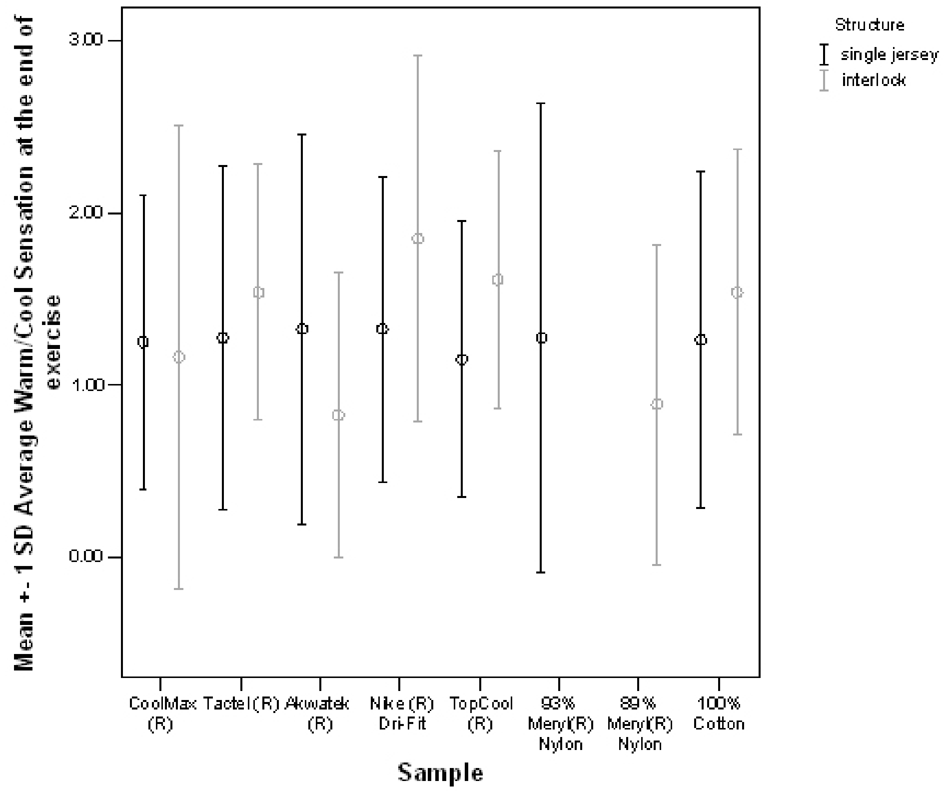


Fig. 4.11 Average warm/cool sensations of 4 subjects by wearing 14 samples at the end of exercise

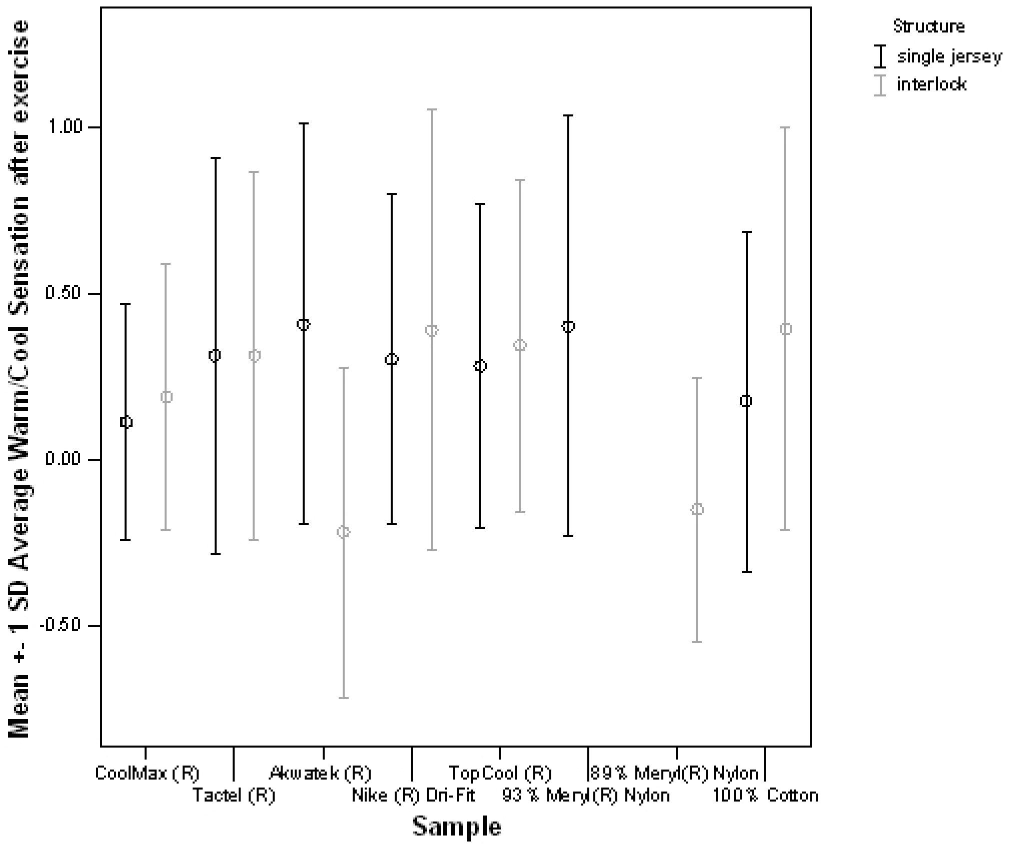


Fig. 4.12 Average warm/cool sensations of 4 subjects by wearing 14 samples after exercise

For the single jersey T-shirts, 100% Cotton T-shirt was rated as the cooler garment and Tactel® was rated as the warmer garment at the beginning of the exercise; Nike® Dri-Fit and 100% Cotton were rated as the cooler garments and Tactel® was rated as the warmer garment in the middle of exercise; TopCool® T-shirt was rated as the cooler garment at the end of exercise but the others had the similar subjective sensations; CoolMax® T-shirts were rated as the cooler garments and Akwatek® and 93% Meryl® Nylon were rated as the warmer garments after exercise. At the beginning of exercise, there was no more heat generated and sweats presented on the skin surface, so the wearer would find difficult to identify the warmth sensation accurately. It might be dependent on the thickness or softness of the fabrics, so the cotton with softer and thinner properties was sensed cooler than Tactel®. In the middle of exercise, the heat generated rapidly and the body temperature increased faster and started to sweat. Nike® Dri-fit and 100% cotton have good air permeability and hence were cooler than Tactel® in this stage because of assistance in heat balance. At the end of exercise, TopCool® was rated to be the coolest T-shirt for its excellent performance in thermal transmission. After exercise, the skin temperature would gradually decrease after a peak, air permeability was also very important in this period of time. Thus, CoolMax® with higher air permeability value was rated as more comfortable, and 93% Meryl® Nylon was rated as more uncomfortable. Akwatek® single jersey also had a good air permeability, but it was rated as warmer T-shirt probably because it has a higher thermal insulation, which was also a factor to affect the judgment of the wearer.

For interlock t-shirts, it could be seen that Akwatek® was rated as cooler in different stages of wearer trials and 89% Meryl® Nylon also carried cooler feeling to the wearer at the end of exercise and after exercise. According to the laboratory testing results, Akwatek® interlock fabrics had good permeability, thermal transmission, water absorption and water vapor transmission, so this fabric would transfer the heat generated by exercise effectively. As a result, the wearer might feel cooler during different stages of exercise. Moreover, 89% Meryl® Nylon also had low value in thermal insulation which was very important when the wearer had a high skin temperature and humidity, so it was rated as a more comfortable T-shirt in trems warmth sensations.

CoolMax® interlock T-shirt was rated as the warmer garment at the beginning of the exercise; Nike® Dri-Fit and TopCool® were rated as the warmer garments in the middle of exercise; Nike® Dri-fit interlock T-shirt was rated as the warmer garment at the end of exercise; Nike® Dri-Fit and 100%Cotton interlock T-shirts were rated as the warmer garments after exercise. At the beginning of the exercise, the wearer might refer to the fabric's initial warmth feeling to judge the T-shirts though the fabrics had similar value in it. It was probably because CoolMax® carried a relative warmer sensation to the wearer at the initial touching. In the middle of the exercise, TopCool® interlock T-shirt with a poor performance in air permeability and thermal insulation resulted in not enough efficiency to release the heat generated rapidly, so the wearer felt it as the warmer T-shirt in this period. And Nike® Dri-Fit was poor in thermal conduction according to our laboratory results, so it was more difficult to transfer heat than the others. As a result, it was rated as the warmer garments after running for 10 minutes. After exercise, the heat was not generated but the skin temperature was reached to a peak, the rate of air exchange through the T-shirt was rated as more important in this stage, so 100% cotton which had a lower air permeability would lead to a hotter feeling to the wearer.

Skin Wetness Sensations

In Fig. 4.13-16, they plotted the average skin wetness feelings of 4 subjects by wearing 14 samples in different stages of wearer trials.

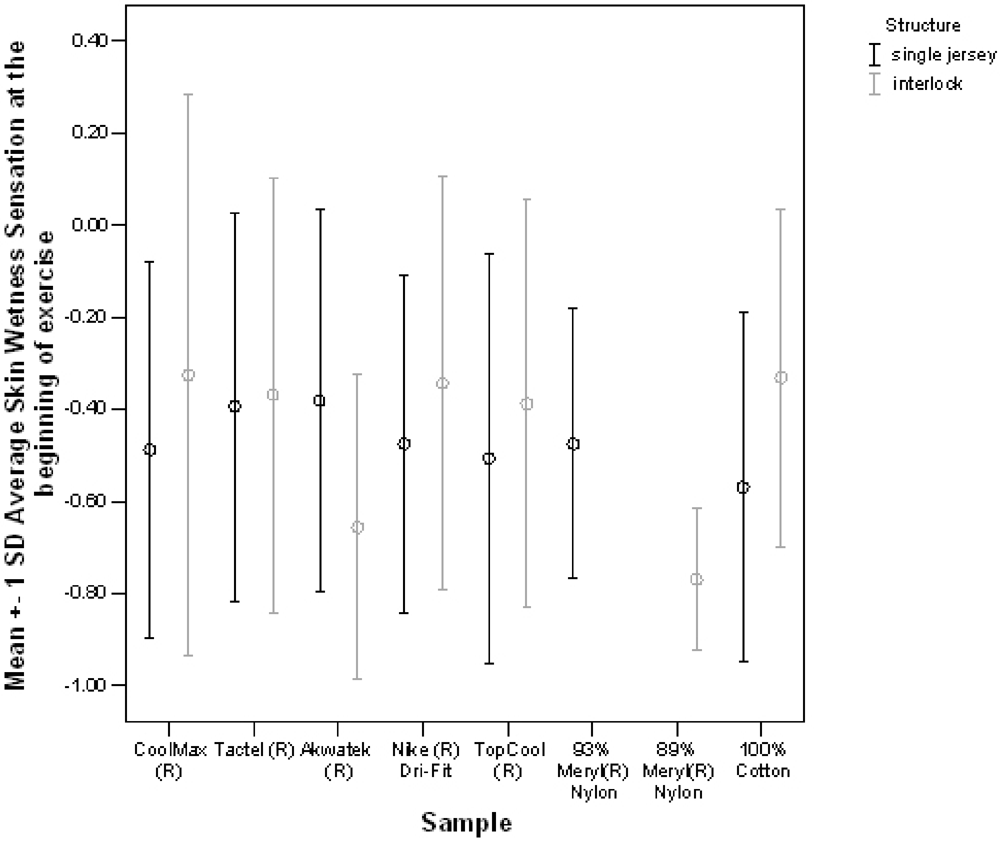


Fig. 4.13 Average skin wetness sensations of 4 subjects by wearing 14 samples at the beginning of exercise

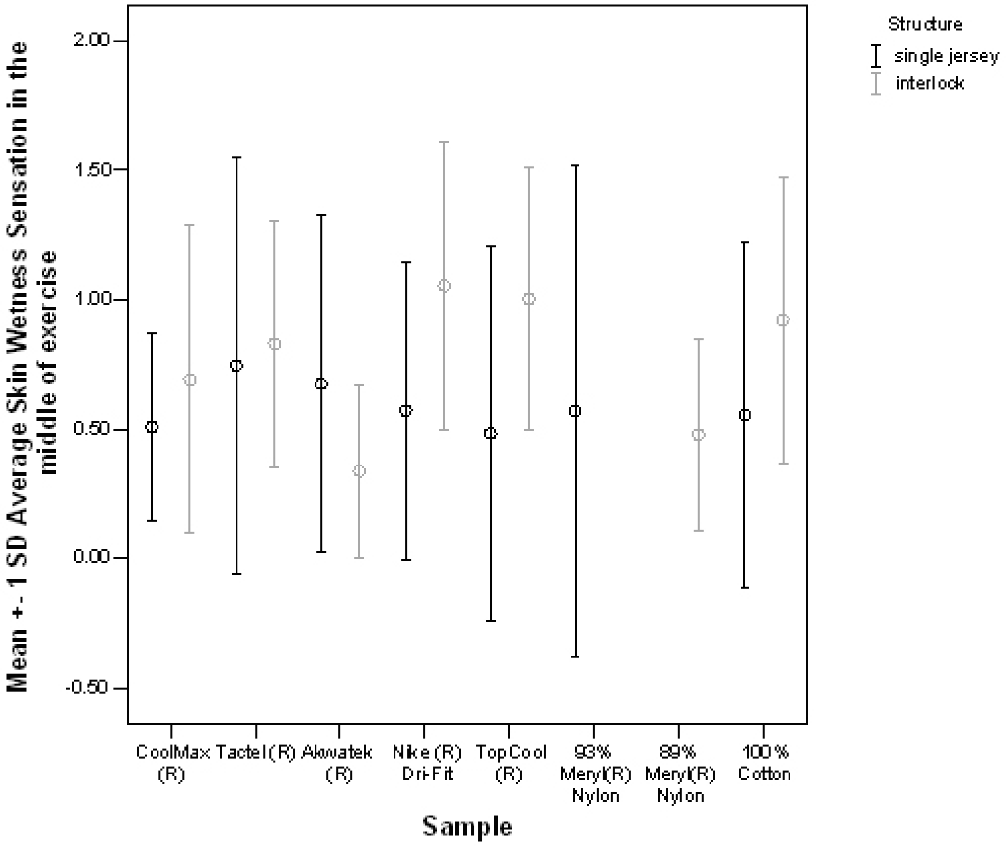


Fig. 4.14 Average skin wetness sensations of 4 subjects by wearing 14 samples in the middle of exercise

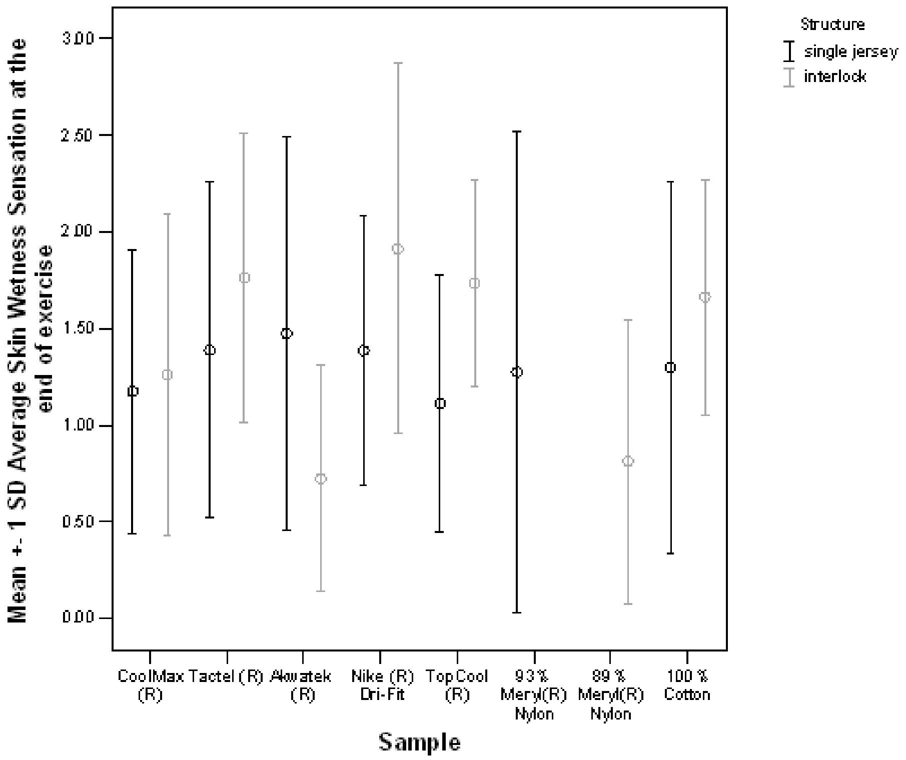


Fig. 4.15 Average skin wetness sensations of 4 subjects by wearing 14 samples at the end of exercise

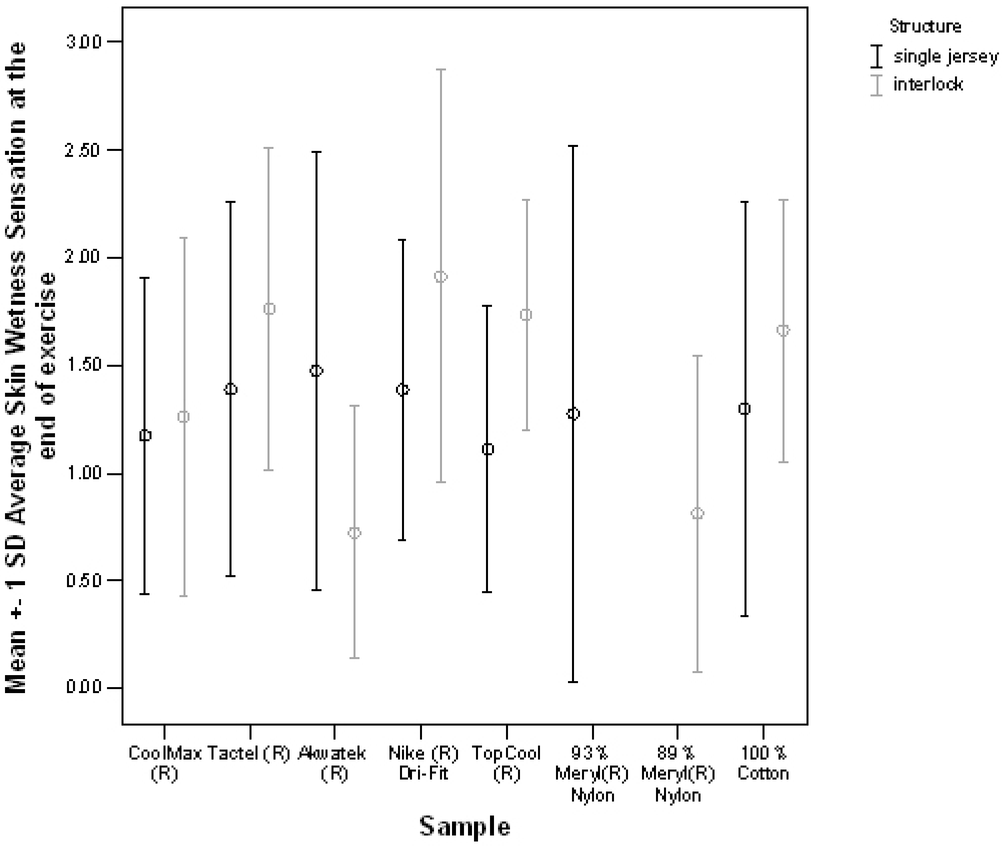


Fig. 4.16 Average skin wetness sensations of 4 subjects by wearing 14 samples after exercise

For the single jersey knitted T-shirts, it's found that 100% Cotton was rated as the drier T-shirt and Akwatek® and Tactel® were rated as wetter T-shirts at the beginning of exercise; CoolMax® and TopCool® were rated as the drier garment and Tactel® was rated as the wetter garment in the middle of exercise; TopCool® was rated as the drier T-shirt and Akwatek® was rated as the cooler T-shirt at the end of exercise; TopCool® was rated as the drier T-shirt and 93% Meryl® Nylon and Akwatek® were rated as the wetter T-shirts after exercise.

At the beginning of exercise, there was no big change in the skin wetness and sweats presented on the skin surface, so it may be not easy for the wearer to identify their wetness sensation. Thus, their sensations might be affected by their warmth sensations which were basically dependent on the packing density and thickness of the fabrics. In the middle of exercise, the skin temperature increased rapidly, so the sweats were generated to balance the heat. CoolMax® with a good performance in air permeability and TopCool® with good heat transmission and fast water absorption resulted in transferring the moisture efficiently in order to keep thermal balance. Thus, they were rated as drier T-shirts. However, Tactel® T-shirt had higher value in thermal insulation and poor in air permeability, so the sweats would be trapped under the garment and resulted in higher skin wetness. At the end of exercise, the increase of skin wetness became slowly, so thermal transmission was more important in this stage. Although Akwatek® had good performance in air permeability and water absorption because it modifies the chemistry of PET and releases hydrophilic groups at the molecular level, the thermal insulation would be affected by the electrochemical process. Thus, it affected the heat transfer and then resulted in higher thermal insulation value and average skin temperature. In this period, the human body of the wearer was very wet and they might be difficult to compare the skin wetness of the T-shirts accurately. Thus, the average skin temperature or their warmth sensation would affect their wetness sensation in this moment, so Akwatek® was rated as the wetter T-shirt at the end of the exercise. Moreover, TopCool® had a lower value in thermal insulation, so it was rated as drier T-shirt. After exercise, the sweating rate would be reduced and the T-shirt was responsible for absorbing the sweats and transfer as moisture to the environment. 93% Meryl® Nylon was obviously poor of water absorption than the others and TopCool® was the relatively better performance in it.

For the interlock knitted T-shirts, 89% Meryl® Nylon and Akwatek® were rated as the drier T-shirts and CoolMax®, 100% Cotton and Nike® Dri-Fit were rated as the wetter T-shirts at the beginning of exercise; Akwatek® was rated as the drier T-shirt and Nike® Dri-Fit and TopCool® were rated as the wetter garments in the middle of exercise; Akwatek® and 89% Meryl® Nylon were rated as the drier T-shirt and Nike® Dri-Fit was rated as the wetter T-shirt at the end of exercise; Akwatek® was rated as the drier T-shirt and 100% Cotton was rated as the wetter T-shirt after exercise.

As mentioned, it might be difficult for the wearers to sense the skin wetness if there was no sweats present on the skin surface at the beginning of exercise, so their sensations might be affected by their warmth sensations which were basically dependent on the packing density and thickness of the fabrics. In the middle of exercise, the skin temperature and humidity were increase rapidly, so the moisture and thermal transmission were relatively important in this stage. The T-shirts with better air permeability, lower thermal insulation value and lower water vapor resistance would result in more comfortable in wetness sensation because the heat and moisture transfer could be more effectively. Therefore, the Akwatek® would be felt drier and Nike® Dri-Fit and TopCool® carried wetter feeling to the wearer. At the end of exercise, there was no big change in the skin wetness. The efficiency of the heat transfer was very important in this stage to keep thermal balance. Similar with the results in single jersey, Akwatek® and 89% Meryl® Nylon had a lower value in thermal insulation, so they would not be a barrier to the heat transfer. On the other hand, Nike® Dri-Fit had a fair performance in it but the wetness sensation of the wearers at this period would be affected by the previous performance during the wearer trial. After exercise, T-shirt with better performances in sweat absorption and moisture transmission was preferable to absorb the sweat and transfer to the environment quickly. Thus, Akwatek® which had good water absorption performance and lower water vapor resistance was rated as drier, and 100% Cotton had the worst performance in these two areas and was rated as wetter T-shirt.

Overall Comfort Sensations

In Fig. 4.17-20, they plotted the average comfort sensations of the subjects by wearing 14 samples at different stages of the wearer trial.

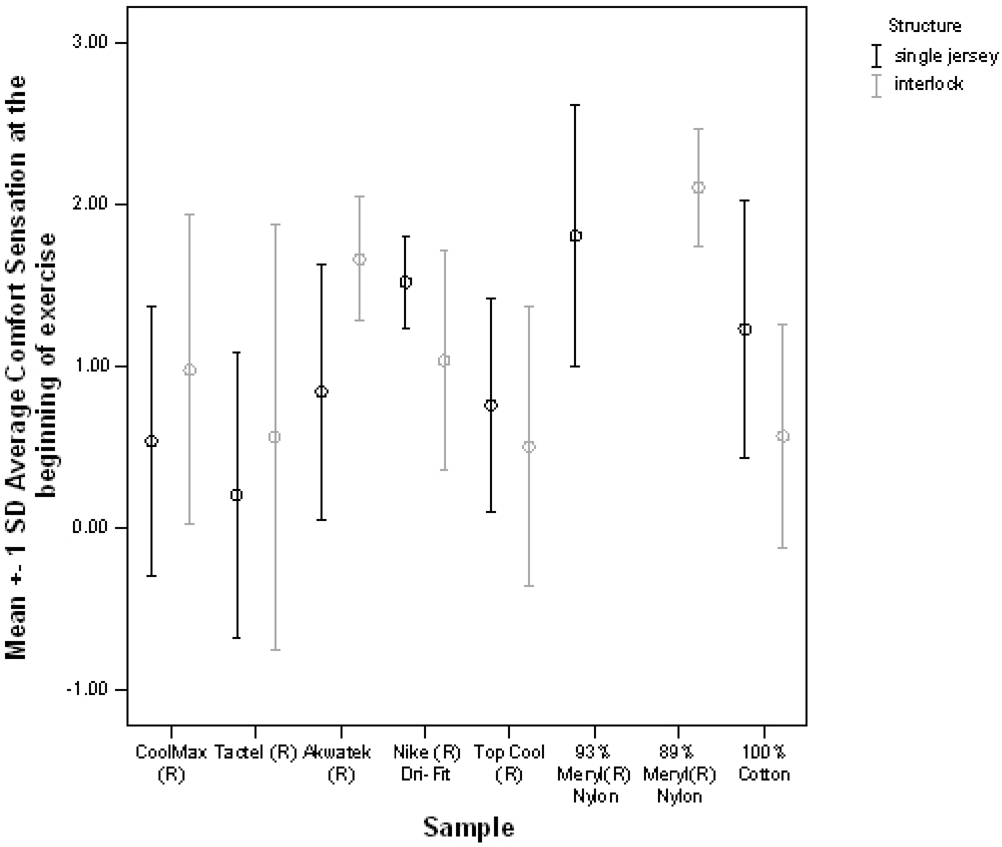


Fig. 4.17 Average comfort sensations of 4 subjects by wearing 14 samples at the beginning of exercise

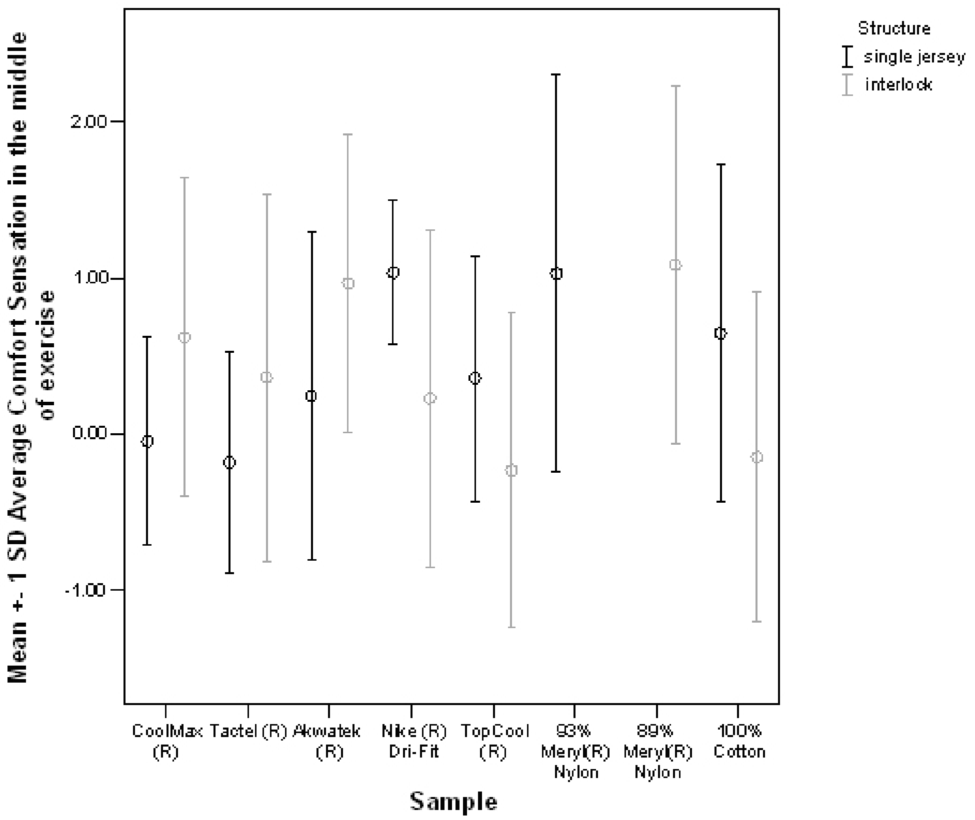


Fig. 4.18 Average comfort sensations of 4 subjects by wearing 14 samples in the middle of exercise

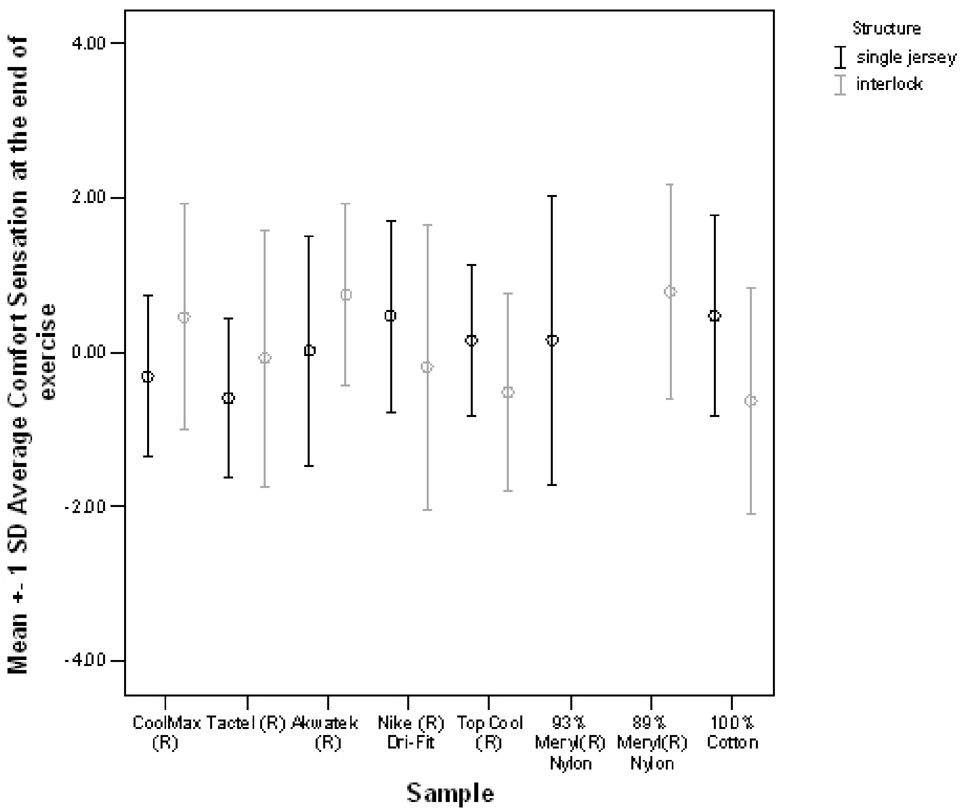


Fig. 4.19 Average comfort sensations of 4 subjects by wearing 14 samples at the end of exercise

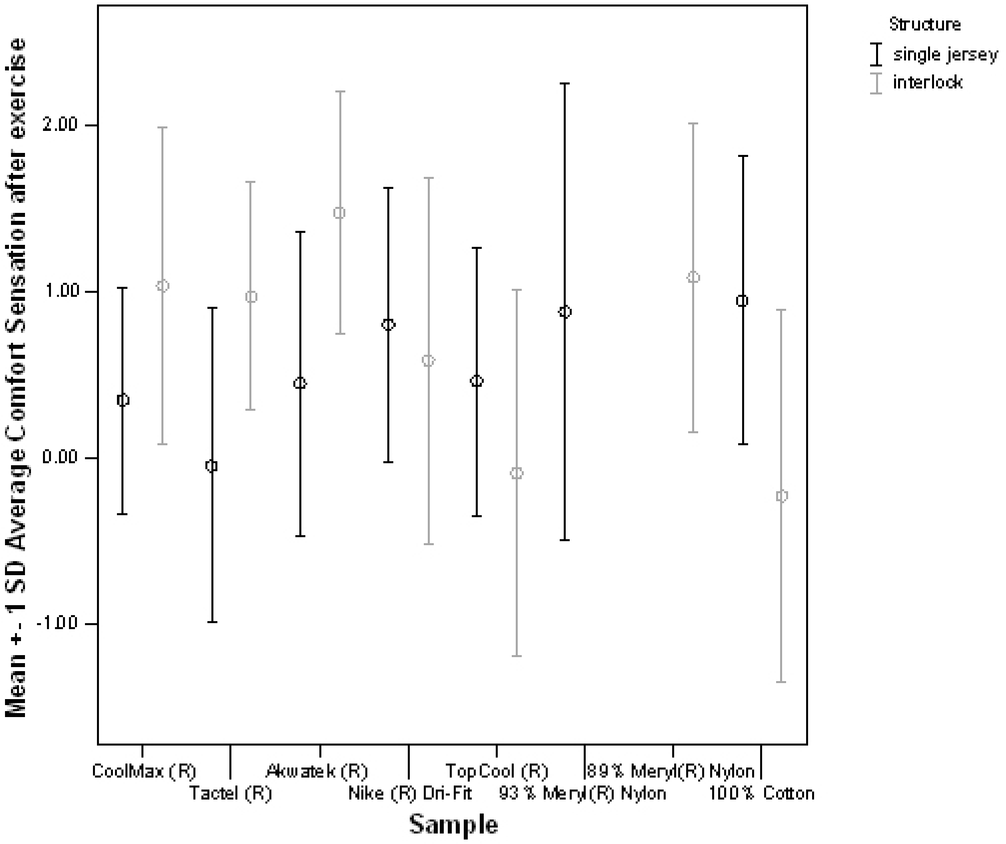


Fig. 4.20 Average comfort sensations of 4 subjects by wearing 14 samples after exercise

It was assumed that the subjectively comfort sensations would be affected by their warmth and wetness feeling of their body. However, the results had some differences with our assumption. For the single jersey knitted T-shirts, Tactel® was rated as the most uncomfortable T-shirt in different stages of wearer trial. 93% Meryl® Nylon and Akwatek® were rated as more comfortable at the beginning of exercise; 93% Meryl® Nylon and Nike® Dri-Fit were rated as more comfortable in the middle of exercise; Nike® Dri-fit and 100% cotton were rated as more comfortable at the end of exercise; 100% cotton, 93% Meryl® Nylon and Nike® Dri-fit were rated as more comfortable after exercise.

At the beginning of the exercise, the results of the overall comfort sensation were not absolutely consisted with the warmth and wetness sensations. 100% Cotton was judged as the cooler and drier garment but it was not rated as the most comfortable one. It might be because the comfort sensation at the beginning was also affected by the mechanical properties of the T-shirt fabrics. 93% Meryl® Nylon and Akwatek® were relatively smoother and softer than the others. These properties were also considered by the wearer during judging the overall comfort. But the most uncomfortable T-shirt was Tactel® which was considered as warmer and wetter in this period. In the middle of exercise, the skin temperature and humidity increased rapidly, so the comfort sensation might be more related to the warmth and wetness sensations. According to the results of the skin wetness sensations, the difference of the ratings between the single jersey T-shirts was not significant, so the wearer might be difficult to judge the overall comfort sensation without extreme cases. Thus, the overall comfort sensation might refer to the rating of warmness. At the end and after exercise, the relationship between the comfort sensation and the warmth or wetness sensations was not closed. It’s found that the overall comfort feeling in these periods was highly related to the mass per unit area and thickness of the T-shirt fabrics. In fact, the packing density and thickness were two of the main factors of some clothing properties such as thermal insulation and air permeability. Thus a looser structured and thinner T-shirt fabric would be considered as more comfortable because it had relatively fairly good but not excellent in overall thermal performances instead of selecting one which had specific excellent performance in only one property.

4.3.2 Summary of subjective comfort sensations

The subjective comfort sensations in different periods during wearer trials were summarized into the following tables:

Table 4.8 Summary of the warm/cool sensations of 7 different single jersey T-shirts at different periods

Cooler

	At the beginning of exercise	In the middle of exercise	At the end of exercise	After exercise
1	CMs, -0.563	100Cs, 0.4833	TCs, 1.15	CMs, 0.1125
2	100Cs, -0.475	NKs, 0.5083	CMs, 1.25	100Cs, 0.175
3	93Ms, -0.3875	93Ms, 0.5875	100Cs, 1.2625	TCs, 0.2813
4	NKs, -0.3688	AKs, 0.7	93Ms, 1.275	NKs, 0.3
5	TCs, -0.2312	TCs, 0.7042	TTs, 1.275	TTs, 0.3125
6	AKs, -0.125	CMs, 0.75	NKs, 1.325	93Ms, 0.4
7	TTs, 0.1375	TTs, 0.8917	AKs, 1.325	AKs, 0.4063

Warmer

Table 4.9 Summary of the warm/cool sensations of 7 different interlock T-shirts at different periods

Cooler (↑) to Warmer (↓)

	At the beginning of exercise	In the middle of exercise	At the end of exercise	After exercise
1	89Mi, -0.5063	AKi, 0.3625	AKi, 0.825	AKi, -0.2188
2	AKi, -0.4375	89Mi, 0.4708	89Mi, 0.8875	89Mi, -0.15
3	NKi, -0.1625	TTi, 0.8125	CMi, 1.1625	CMi, 0.1875
4	TTi, -0.1313	CMi, 0.8625	TTi, 1.5375	TTi, 0.3125
5	TCi, 0.0125	100Ci, 0.9042	100Ci, 1.5375	TCi, 0.3438
6	100Ci, 0.0188	TCi, 1	TCi, 1.6125	NKi, 0.3875
7	CMi, 0.1438	NKi, 1.0167	NKi, 1.85	100Ci, 0.3938

Table 4.10 Summary of the skin wetness sensations of 7 different single jersey T-shirts at different periods

Drier (↑) to Wetter (↓)

	At the beginning of exercise	In the middle of exercise	At the end of exercise	After exercise
1	100Cs, -0.5688	TCs, 0.4833	TCs, 1.1125	TCs, 0.0875
2	TCs, -0.5663	CMs, 0.5083	CMs, 1.175	100Cs, 0.2187
3	CMs, -0.4875	100Cs, 0.5542	93Ms, 1.275	TTs, 0.2625
4	93Ms, -0.475	NKs, 0.5708	100Cs, 1.3	CMs, 0.2813
5	NKs, -0.475	93Ms, 0.5708	NKs, 1.3875	AKs, 0.3125
6	TTs, -0.3937	AKs, 0.675	TTs, 1.3875	NKs, 0.35
7	AKs, -0.3813	TTs, 0.7458	AKs, 1.475	93Ms, 0.3562

Table 4.11 Summary of the skin wetness sensations of 7 different interlock T-shirts at different periods

Drier ↑ … ↓ Wetter

	At the beginning of exercise	In the middle of exercise	At the end of exercise	After exercise
1	89Mi, -0.7688	AKi, 0.3375	AKi, 0.725	AKi, -0.3625
2	AKi, -0.6562	89Mi, 0.4792	89Mi, 0.8125	89Mi, -0.2563
3	TCi, -0.3875	CMi, 0.6917	CMi, 1.2625	CMi, 0.0187
4	TTi, -0.3687	TTi, 0.8292	100Ci, 1.6625	TCi, 0.3938
5	NKi, -0.3438	100Ci, 0.9208	TCi, 1.7375	TTi, 0.4687
6	100Ci, -0.3313	TCi, 1.0042	TTi, 1.7625	NKi, 0.4875
7	CMi, -0.325	NKi, 1.0542	NKi, 1.9125	100Ci, 0.525

Table 4.12 Summary of overall comfort sensations of different single jersey T-shirts at different periods

More Comfortable ↑ … ↓ More Uncomfortable

	At the beginning of exercise	In the middle of exercise	At the end of exercise	After exercise
1	93Ms, 1.8	NKs, 1.0333	100Cs, 0.475	100Cs, 0.9438
2	NKs, 1.5167	93Ms, 1.0292	NKs, 0.475	93Ms, 0.875
3	100Cs, 1.225	100Cs, 0.6458	TCs, 0.1625	NKs, 0.8
4	AKs, 0.8375	TCs, 03583	93Ms, 0.1625	TCs, 0.4563
5	TCs, 0.7563	AKs, 0.2458	AKs, 0.025	AKs, 0.4438
6	CMs, 0.5313	CMs, -0.0458	CMs, -0.3125	CMs, 0.3438
7	TTs, 0.2	TTs, -0.1792	TTs, -0.5875	TTs, -0.05

Table 4.13 Summary of overall comfort sensations of 7 different interlock T-shirts at different periods

		At the beginning of exercise	In the middle of exercise	At the end of exercise	After exercise
More Comfortable ↑	1	89Mi, 2.1	89Mi, 1.0833	89Mi, 0.7875	AKi, 1.4688
	2	AKi, 1.6563	AKi, 0.9667	AKi, 0.75	89Mi, 1.0812
	3	NKi, 1.0313	CMi, 0.6208	CMi, 0.4625	CMi, 1.0313
	4	CMi, 0.975	TTi, 03625	TTi, -0.075	TTi, 0.9688
	5	100Ci, 0.5625	NKi, 0.2292	NKi, -0.1875	NKi, 0.5813
	6	TTi, 0.5563	100Ci, -0.1458	TCi, -0.5125	TCi, -0.0937
↓ More Uncomfortable	7	TCi, 0.5	TCi, -0.2292	100Ci, -0.625	100Ci, -0.2313

4.4. Skin Temperature and Humidity Measurements

The measurements of mean skin temperature and humidty are listed in Table 4.14.

Table 4.14 Measurement Results of Physiological Responses

Sample	Structure	Mean ± SD	Skin Temperature (oC)							Skin Humidity (%)						
			Chest	Upper back	Lower back	Hand	Shin	Calf	Average	Chest	Upper back	Lower back	Hand	Shin	Calf	Average
CoolMax®	Single Jersey		33.42 ± .60	33.09 ± 1.14	32.75 ± 1.45	30.46 ± 1.86	29.86 ± 1.4	29.04 ± .95	31.65 ± .64	52.5 ± 15.0	53.7 ± 17.1	62.1 ± 20.6	43.4 ± 5.9	41.7 ± 4.5	43.1 ± 5.0	49.8 ± 10.1
	Interlock		33.58 ±.77	33.28 ± 1.04	33.33 ± 1.35	31.12 ± 1.21	30.47 ± 1.27	30.2 ± 1.13	32.17 ± .69	60.9 ± 16.2	63.6 ± 16.3	64.6 ± 16.1	44.5 ± 4.7	43.6 ± 4.1	42.8 ± 4.3	54.2 ± 9.6
Tactel®	Single Jersey		32.73 ± 1.10	33.13 ± 1.07	32.18 ± .97	31.16 ± 2.13	30.43 ± 1.05	28.52 ± 1.26	31.55 ± .67	53.3 ± 15.0	53.7 ± 16.4	64.4 ± 22.0	44.2 ± 10	40.6 ± 4.8	41.4 ± 5.0	50.0 ± 11.3
	Interlock		33.56 ± .57	33.20 ± 1.27	33.51 ± 1.03	30.32 ± 1.7	30.21 ± 1.47	30.52 ± 1.29	32.07 ± .67	56.5 ± 13.6	66.7 ± 19.0	63.4 ± 20.3	46.4 ± 5.3	45.3 ± 5.5	43.0 ± 4.6	54.2 ± 10.0
Akwatek®	Single Jersey		32.87 ± .97	33.68 ± 1.21	32.82 ± 1.46	30.94 ± 1.76	30.53 ± 1.26	29.79 ± 1.65	31.94 ± .91	54.3 ± 13.1	59.8 ± 14.2	60.5 ± 15.9	43.4 ± 6.5	42.2 ± 3.9	43.1 ± 4.5	51.1 ± 9.0
	Interlock		32.56 ± .84	33.63 ± .91	32.87 ± 1.88	30.69 ± 1.89	30.51 ± 1.21	30.23 ± 1.29	31.89 ± .75	50.5 ± 12.9	54.1 ± 17.4	56.7 ± 15.6	44.8 ± 6.5	44.5 ± 5.2	42.0 ± 5.0	49.1 ± 9.8
Nike® Dri-Fit	Single Jersey		32.89 ± 1.05	33.17 ± .93	32.21 ± 1.52	30.86 ± 1.83	30.08 ± 1.01	29.23 ± 1.04	31.59 ± .71	53.8 ± 12.5	60.9 ± 17.9	62.2 ± 16.2	44.3 ± 6.9	43.8 ± 4.9	42.7 ± 5.0	51.8 ± 9.7
	Interlock		32.62 ± .81	32.99 ± 1.21	32.69 ± 1.45	30.54 ± 1.91	29.94 ± 1.56	29.36 ± 1.6	31.52 ± .74	53.3 ± 12.1	57.7 ± 16.5	60.6 ± 16.5	48.5 ± 7.5	45.0 ± 6.0	43.4 ± 6.4	51.8 ± 9.7
TopCool®	Single Jersey		32.86 ± .99	32.82 ± 1.26	31.80 ± 1.06	31.45 ± 1.15	29.57 ± 1.42	28.75 ± 1.13	31.39 ± .69	55.5 ± 13.4	55.8 ± 15.8	65.5 ± 19.6	44.6 ± 7.5	43.7 ± 4.2	43.2 ± 4.8	51.8 ± 10.0
	Interlock		32.32 ± 1.19	33.31 ± .80	32.31 ± 1.39	31.12 ± 1.37	29.43 ± 1.26	28.25 ± .9	31.30 ± .55	53.9 ± 12.3	56.6 ± 15.5	58.1 ± 17.3	42.4 ± 4.4	43.6 ± 4.9	42.9 ± 5.2	50.2 ± 8.7
Meryl® Nylon	Single Jersey		31.72 ± 1.24	33.09 ± 1.29	32.09 ± 1.73	31.04 ± 1.94	30.45 ± .84	29.25 ± 1.37	31.40 ± .77	53.1 ± 15.2	23.6 ± 16.0	64.2 ± 22.3	42.6 ± 4.4	42.5 ± 4.9	42.3 ± 4.4	50.1 ± 10.8
	Interlock		32.23 ± 1.21	32.94 ± 1.08	32.41 ± 1.64	29.9 ± 1.77	29.72 ± 1.85	29.53 ± 1.78	31.28 ± .76	53.2 ± 11.8	56.2 ± 13.3	61.2 ± 16.1	44.5 ± 5.3	43.7 ± 4.9	43.4 ± 4.9	50.8 ± 8.7
100% Cotton	Single Jersey		32.67 ± .86	33.33 ± 1.11	33.33 ± 1.40	31.11 ± 1.69	30.59 ± 1.82	29.50 ± 1.14	31.9 ± . 77	57.6 ± 11.8	60.9 ± 14.2	65.0 ± 13.5	44.0 ± 5.4	45.0 ± 3.5	43.1 ± 4.8	53.3 ± 7.6
	Interlock		32.80 ± .56	33.45 ± .78	31.61 ± 1.26	31.02 ± 1.37	30.13 ± .87	29.88 ± 1.1	31.66 ± .50	49.9 ± 11.3	53.1 ± 13.1	56.2 ± 15.3	43.5 ± 4.2	40.1 ± 3.9	41.0 ± 4.9	47.7 ± 7.5

Fig. 4.21 and Fig. 4.22 showed the trends of the changes of the average skin temperatures by wearing different kinds of T-shirts during wearer trials. In fact, the average skin temperature was gradually increased not more than 2°C during running exercise because of the sorption heat generation and heat exchange between clothing and ambient temperature. After exercise, the average skin temperature increased suddenly to a peak within 5 minutes and then dropped gradually to cool down which is probably due to the fact that the body continued to generate heat for a while after the exercise terminates, or the heat released from the absorption of moisture by the T-shirt fabrics.

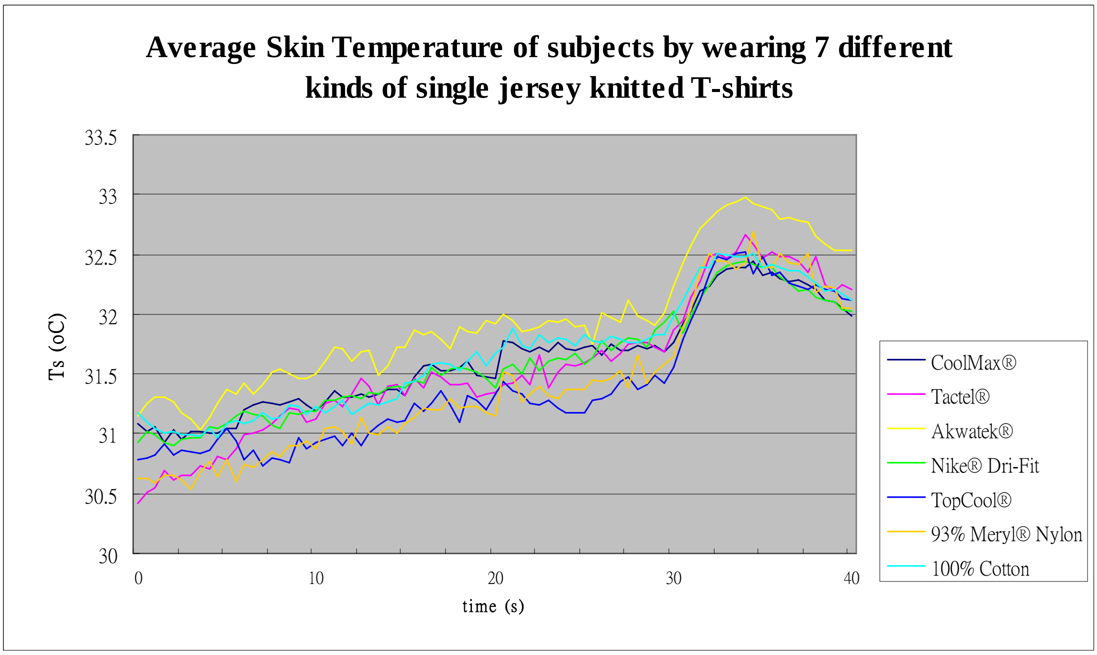


Fig. 4.21 Average skin temperature of subjects by wearing single jersey T-shirts

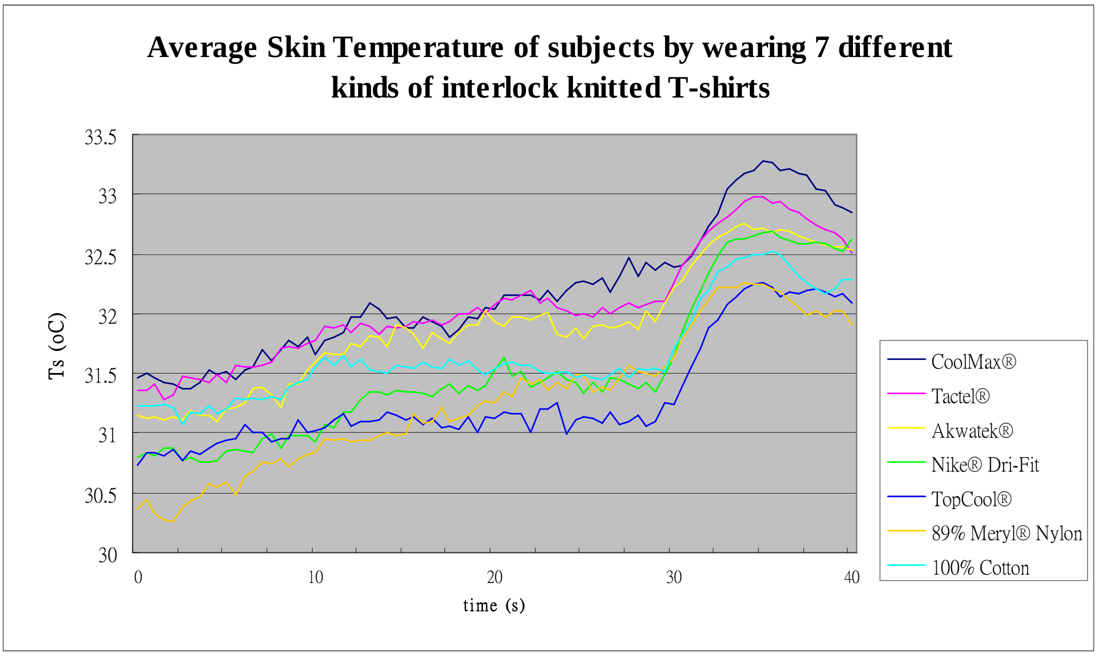


Fig. 4.22 Average skin temperature of subjects by wearing interlock T-shirts

Fig. 4.23 and Fig. 4.24 show the changes of the skin humidity of the wearers by wearing different knitted T-shirts during wearer trials. The increase of skin humidity at the first 5 minutes was not obvious with only a few degree of humidity. After 5 minutes of running exercise, the skin humidity increase rapidly (more than 15% of skin humidity). From 20 to 30 minutes of running exercise, the skin humidity were increase gradually again. After running and then taking rest for 10 minutes, the skin humidity was decreased quickly.

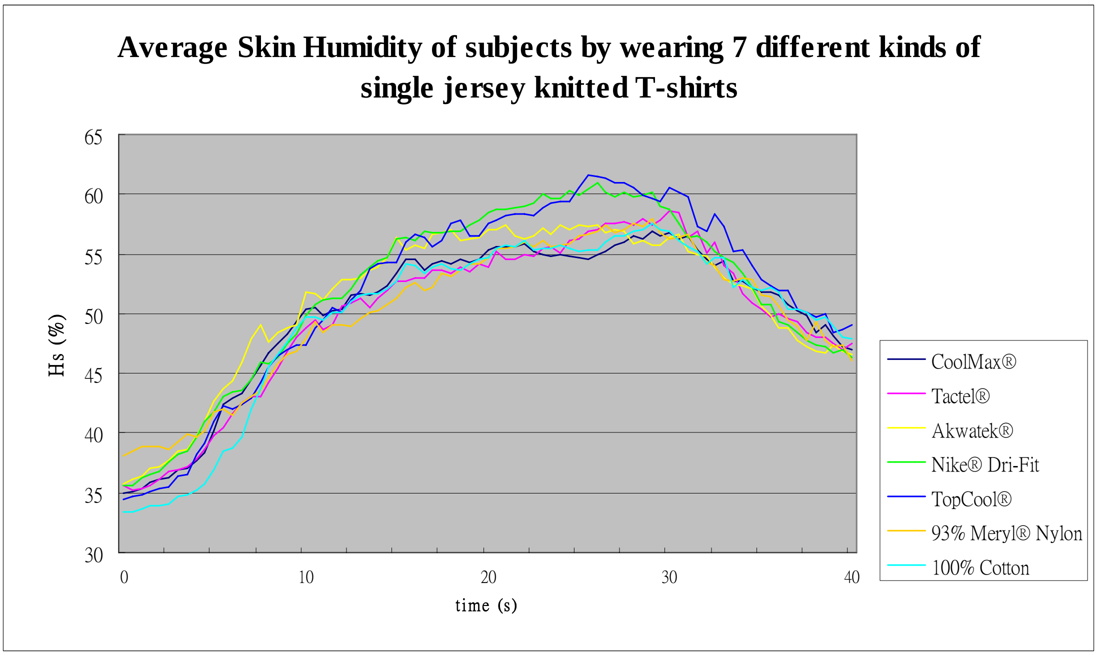


Fig. 4.23 Average skin humidity of subjects by wearing single jersey T-shirts

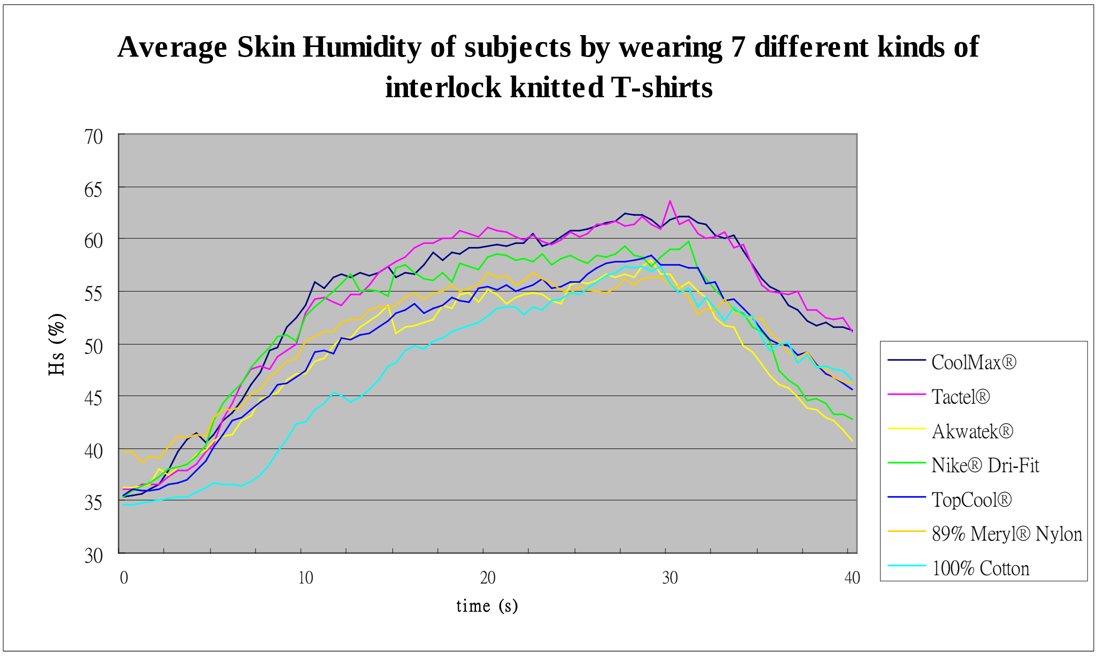


Fig. 4.24 Average skin humidity of subjects by wearing interlock T-shirts

Because of the significant temperature and humidity profiles at different stages of exercise, the entire period was divided into 4 stages to analyze, including period at the start of running exercise (0 – 5 minutes), in the middle of the running exercise (10 – 20 minutes), at the end of the running exercise (20 – 30 minutes), and after running exercise (30 – 40 minutes).

In our study, for the single jersey knitted T-shirts, it's found that the average skin temperature of the wearers by wearing TopCool® and 93% Meryl® Nylon single jersey T-shirts was lower than the others. And Akwatek® single jersey T-shirt resulted in higher average skin temperature during the wearer trials. On the other hand, wearers by wearing 93% Meryl® Nylon or 100% Cotton had the lower average skin humidity and TopCool® and Nike® Dri-Fit had the higher results.

For the interlock T-shirts, TopCool® and 89% Meryl® Nylon resulted in lower average skin temperature of the wearers, and CoolMax® resulted in higher average skin temperature. For the average skin humidity, the wearers by wearing 100% Cotton had relatively lower skin humidity during the wearer trial, and by wearing Tactel® or CoolMax® resulted in higher average skin humidity.

However, in the tested T-shirts, the physiological responses had no clear correlation to either the fabric properties or comfort sensations. This may be due to the fact that there are large variations in physiological responses among the wearers and these also vary from time to time, and on the other hand, the effects of fabrics properties are relatively small.

CHAPTER 5

RELATIONSHIPS BETWEEN OBJECTIVE MEASUREMENTS, PHYSIOLOGICAL RESPONSES AND CLOTHING COMFORT SENSATIONS

5.1 Introduction

In this chapter, the relationship between objective measurements, different moisture transmission tests, clothing properties and comfort sensations, and thermoregulation and clothing comfort sensations are analyzed respectively in detailed.

5.2 Relationships between different clothing properties

Table 5.1 gives a summary of the correlations between different testing results. It is reasonable to see that there is a strong relationship between the mass per unit area and the air permeability. The mass per unit area was high that might represent that the yarns were closely packed, so it results in lesser air flow through the fabrics. So that it is also inversely related to water vapor transmission rate of fabrics. On the other hand, it's also found that the air permeability was conversely related to the moisture regain. A high amount of moisture would present in yarn or between the yarns. It might result in resisting the air flowing through the fabric because the moisture might present in the pores.

Table 5.1 Relationship between different objective measurements

		mass per unit area (g/m2)	thickness (mm)	Air Permeability (cm3/s/cm2)	thermal insulation (clo)	q-max (W/cm2)	Water Vapor Transmission Rate (g/hr.m2)	Wicking level (cm) at 5 mins	Moisture Regain (%)	Thermal Insulation by Walter (m2oC/W)	Water Vapour Resistance by Walter (m2Pa/W)
mass per unit area (g/m2)	Pearson Correlation	1	.447	-.690(**)	.038	.400	-.650(*)	-.421	.360	.052	.507
	Sig. (2-tailed)	.	.109	.006	.898	.156	.012	.134	.206	.860	.064
	N	14	14	14	14	14	14	14	14	14	14
thickness (mm)	Pearson Correlation	.447	1	-.134	.821(**)	-.381	-.374	-.077	.432	-.005	.675(**)
	Sig. (2-tailed)	.109	.	.648	.000	.179	.188	.793	.123	.988	.008
	N	14	14	14	14	14	14	14	14	14	14
Air Permeability (cm3/s/cm2)	Pearson Correlation	-.690(**)	-.134	1	.281	-.472	.407	.446	-.599(*)	.229	-.252
	Sig. (2-tailed)	.006	.648	.	.331	.088	.149	.110	.024	.432	.385
	N	14	14	14	14	14	14	14	14	14	14
thermal insulation (clo)	Pearson Correlation	.038	.821(**)	.281	1	-.777(**)	-.071	.348	-.027	.109	.453
	Sig. (2-tailed)	.898	.000	.331	.	.001	.810	.222	.926	.710	.104
	N	14	14	14	14	14	14	14	14	14	14
q-max (W/cm2)	Pearson Correlation	.400	-.381	-.472	-.777(**)	1	-.281	-.584(*)	.314	-.185	-.149
	Sig. (2-tailed)	.156	.179	.088	.001	.	.331	.028	.274	.526	.612
	N	14	14	14	14	14	14	14	14	14	14
Water Vapor Transmission Rate (g/hr.m2)	Pearson Correlation	-.650(*)	-.374	.407	-.071	-.281	1	.486	-.115	.371	-.769(**)
	Sig. (2-tailed)	.012	.188	.149	.810	.331	.	.078	.695	.192	.001
	N	14	14	14	14	14	14	14	14	14	14
Wicking level (cm) at 5 mins	Pearson Correlation	-.421	-.077	.446	.348	-.584(*)	.486	1	-.527	.296	-.320
	Sig. (2-tailed)	.134	.793	.110	.222	.028	.078	.	.053	.303	.264
	N	14	14	14	14	14	14	14	14	14	14
Moisture Regain (%)	Pearson Correlation	.360	.432	-.599(*)	-.027	.314	-.115	-.527	1	-.126	.139
	Sig. (2-tailed)	.206	.123	.024	.926	.274	.695	.053	.	.668	.636
	N	14	14	14	14	14	14	14	14	14	14
Thermal insulation by Walter (m2oC/W)	Pearson Correlation	.052	-.005	.229	.109	-.185	.371	.296	-.126	1	-.377
	Sig. (2-tailed)	.860	.988	.432	.710	.526	.192	.303	.668	.	.184
	N	14	14	14	14	14	14	14	14	14	14
Water Vapour Resistance by Walter (m2Pa/W)	Pearson Correlation	.507	.675(**)	-.252	.453	-.149	-.769(**)	-.320	.139	-.377	1
	Sig. (2-tailed)	.064	.008	.385	.104	.612	.001	.264	.636	.184	.
	N	14	14	14	14	14	14	14	14	14	14

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

According to the literature review, there were some researchers who had conducted researches to prove the relationship between the thermal insulation and thickness. In our research, we also proved it with a high correlation index. Moreover, the water vapor resistance had also a significant relation with the thickness. It's no doubt that the water vapor would be difficult to transfer from the human skin through a thicker fabric to the environment.

For the similar clothing properties, it can be found that the water vapor transmission rate measured by ASTM E96 Cup Method is highly related to water vapor resistance measured by Walter. The detailed explanations would be discussed in 5.3. However, the relationship of thermal insulation values measured by Thermo Labo II and Walter is very weak. It is dependent on their differences in temperature gradients of the experimental conditions and their parameters. Moreover, the heat transfer mechanism is more complicated of a garment than a fabric. As a results, their relationship is not good.

5.3 Relationships between different moisture transmission tests

As Moisture Transmission Tester, ASTM E96 testing method, Sweating Guarded Hot Plate and Sweating Manikin (Walter) were used to measure the moisture transmission or water vapor resistance of fabrics or garment, it's useful to compare the results and study the relationship between them.

Due to the limited quantity of some fabric samples, only functional fabrics were included in this comparison. These fabrics include CoolMax®, Tactel®, Akwatek® and TopCool® interlock and single jersey fabrics. Moisture Transmission Test and

ASTM E96 Cup Method are used to measure the water vapor transmission rate which expressed in the same unit (g/hm^2), and Sweating Hot Plate and Sweating Manikin are used to measure the water vapor resistance which expressed in another unit (m^2Pa/W). The testing results are shown in Table 5.2.

Table 5.2 Testing Results of four different kinds of moisture measurements

				Water Vapor Transmission Rate (g/hm^2)		Water Vapor Resistance (m^2Pa/W)	
Sample	Brands	Structure		Moisture Transmission Test (Model CS 141)	ASTM E96 Water Vapor Transmission Test	Novel Sweating Guarded Hot Plate Test	Test by Thermal Manikin
1	CoolMax®	single jersey	Mean ± SD	3.818 ± .093	20.48 ± .91	3.27 ± .366	22.10 ± .51
2	CoolMax®	interlock	Mean ± SD	3.817 ± .056	20.72 ± 1.14	2.928 ± 1.01	22.44 ± .74
3	Tactel®	single jersey	Mean ± SD	3.064 ± .227	20.40 ± .85	4.062 ± .338	22.58 ± .26
4	Tactel®	interlock	Mean ± SD	3.733 ± .214	20.75 ± .67	1.97 ± .494	22.17 ± .22
5	Akwatek®	single jersey	Mean ± SD	4.760 ± .232	21.78 ± .88	1.662 ± .232	21.49 ± .35
6	Akwatek®	interlock	Mean ± SD	4.798 ± .643	21.79 ± 2.67	1.449 ± .21	21.44 ± .17
7	TopCool®	single jersey	Mean ± SD	3.478 ± .247	21.15 ± 1.11	2.75 ± .63	22.04 ± .48
8	TopCool®	interlock	Mean ± SD	3.207 ± .392	19.99 ± .81	4.641 ± .279	23.06 ± .39

Although both Moisture Transmission Test and ASTM E96 Cup Method measure the moisture transmission rate, the measurement conditions are very different. In the former test, water vapor is transferred from the wet side to a closed area without air movement, whereas in the latter test moisture is transmitted to an opening environment of constant humidity of 65% r.h. with air movement. Thus, the moisture transmission rate measured by Moisture Transmission Tester is smaller than ASTM E96 Cup Method.

Moreover, water vapor resistance measured by Sweating Hot Plate and manikin are also expressed in the same unit, but the difference between the values is large because one is measuring the fabric and the other is measuring the garments. In the manikin test, there are many additional factors influencing the results, such as the air gap between the skin and garment, the distributions of water vapor resistance at different body parts.

A moderate relationship is observed between Moisture Transmission Testing Method (Model CS-141) and ASTM E96 Cup Method, which is shown Fig. 5.1. It is observed that sample 7 and 8 tend to fall away from the linear relationship. Sample 7 is measured with a higher value by ASTM E96 Cup Method and Sample 8 is measured with a higher value by Moisture Transmission Tester. Sample 7 is composed of 11% Lycra, on which moisture may be more easily condensed to block the pores of the fabric for moisture transmission. As a result, the measured moisture transmission rate of the fabric is benefited from the more open environment of ASTM E96 Cup Method For Sample 8, which was the thickest fabric tested, the fabric may absorb more moisture during the tests, resulting a lower measured value. Since the amount of absorption depends on the time lapse during testing, more absorption took place in the ASTM E96 Cup method (which lasted 5 days for each test), consequently the test results from the ASTM E96 Cup method is relatively lower. Since the Moisture Transmission Tester measured the fabric for just one to two hours, so the moisture transmission rate of such thicker fabric may have a relatively higher value by using Moisture Transmission Tester.

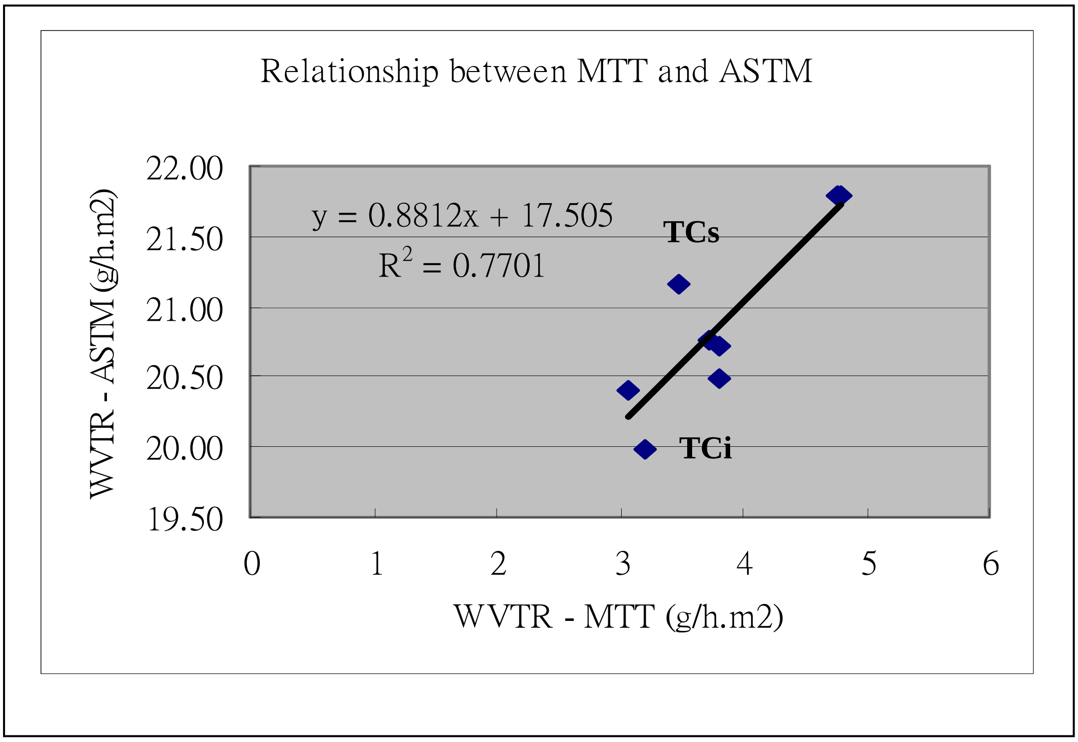


Fig. 5.1 Relationship between Moisture Transmission Test and ASTM E96 Cup Method

Fig. 5.2 plots the relationship between the results from the Sweating Guarded Hot Plate and those from the ATSM E96 Cup Method. As can been seen, there is a good correlation between the results from the sweating hot plate and those from the ASTM E96 Cup Method. Although Gibson [109] undertook such an investigation previous, his work did not include the functional T-shirt fabrics we have tested. Furthermore, the testing method in our sweating hot plate is slightly different from that specified in ISO 11092:1993 (E) in that the water vapor resistance is calculated by the slopes of 5 layers of fabrics. Comparing with Fig. 5.3, a slightly higher relationship is found between the Moisture Transmission Test (model CS-141) and Sweating hot plate, probably both tests were conducted under relatively high water vapor pressure gradients.

Moreover, it is observed that the water vapor resistance of Sample 4 measured by Sweating Guarded Hot Plate tends to fall lower than what the trendline predicts. This may be because Sample 4 is a two layer moisture management fabric with the inner layer transferring moisture towards the more absorbent outer layer where it evaporates efficiently. As 5 layers of fabrics are measured by Sweating Guarded Hot Plate, fabric with effective moisture absorption and transmission of each layer results in highly decrease in water vapor resistance.

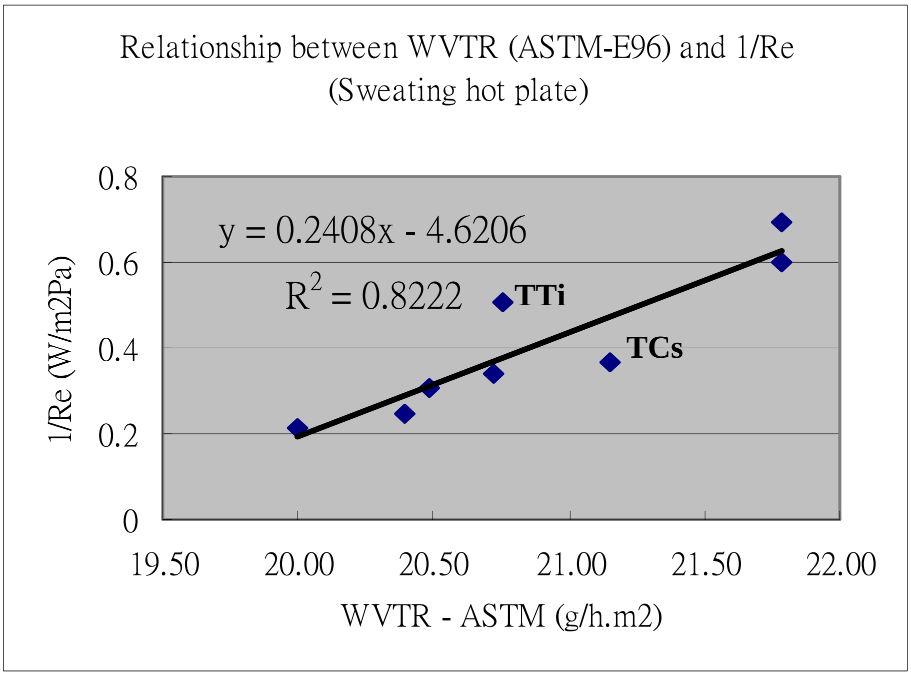


Fig. 5.2 Relationship between ASTM E96 Cup Method and Sweating Hot Plate

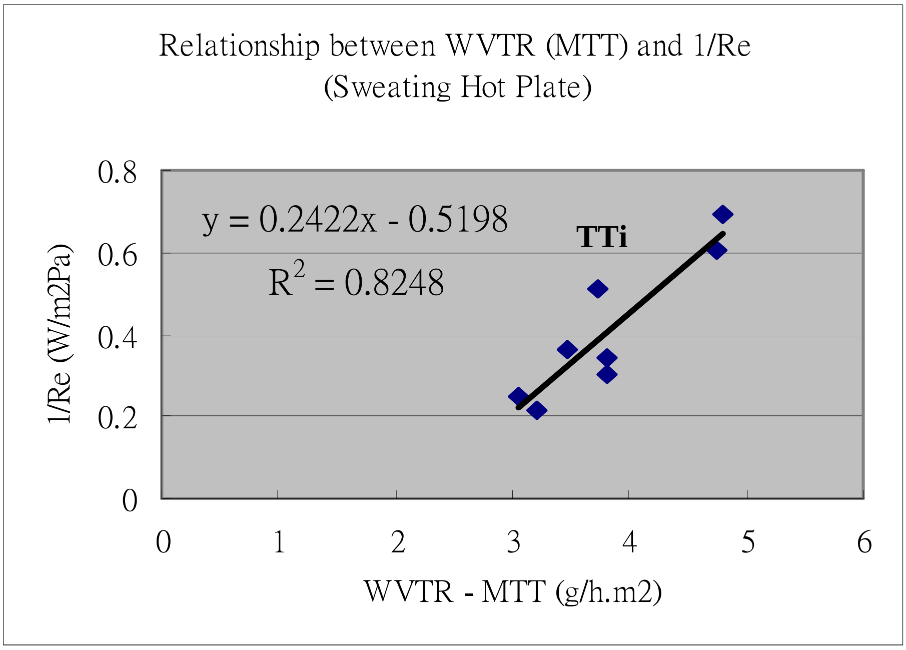


Fig. 5.3 Relationship between Moisture Transmission Test and Sweating Hot Plate

By comparing fabric and garment testing method, a relatively high relationship is observed in Fig. 5.4. The measurements of them are conducted under similar environmental condition which may be the key reason for the good correlation. Sample 4 has little smaller value in water vapor resistance measured by Sweating Guarded Hot Plate and it has been explained. For sample 2, it results in higher water vapor resistance measured by thermal manikin. It may be because of comparative lower weight of the garment, resulting greater air gap between the manikin and the garment during the manikin testing.

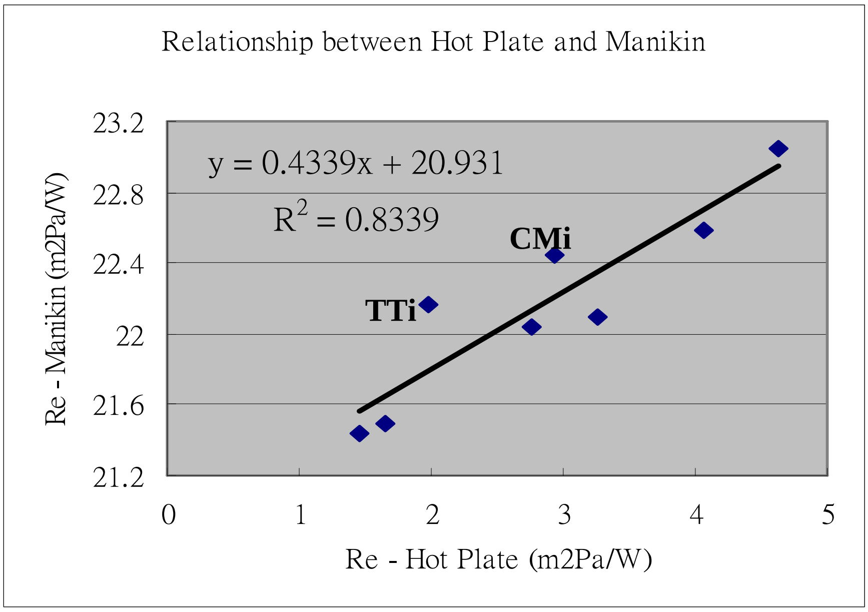


Fig. 5.4 Relationship between Sweating Hot Plate and Sweating Manikin

5.4 Relationships between the subjective thermal comfort sensations

According to Appendix K1-4, it showed the closed correlations between the subjective thermal comfort sensations. That means the overall comfort sensations of the wearer were affected by their warmth and the skin wetness sensations of their body skin.

On the other hand, Appendix K1-4 states that warm/cool sensation is the primary factor of the overall comfort sensation during running and skin wetness sensation become more related to comfort sensation after exercise, where Fig. 5.5-7 plot the relationships between the warm/cool sensation and the overall comfort feeling at different periods of running and Fig. 5.8 plots the relationship between the wetness and comfort sensations. It reflects that the subjects are more sensitive to the increase of their body heat than the present of sweats during continuous exercise, but it is opposite after exercise. For the previous researches, they are contrary to our finding. As our samples are functional T-shirts which are claimed to transmit the moisture and absorb the sweats in a rapid rate, the wetness differences between the garments are not obvious. So, there may have differences with the previous results. And, as mentioned in Section 2.1, there are no humidity receptors of the body. A rapid increase of body temperature influences the sensitivity of sweating, so their comfort sensations are affected mainly by warmth sensation during exercise. After exercise, no serious movement of their bodies would arise their sensitivity of the dampness. Present of the sweats on the skin is much more easier to be sensed than the amount of heat generated.

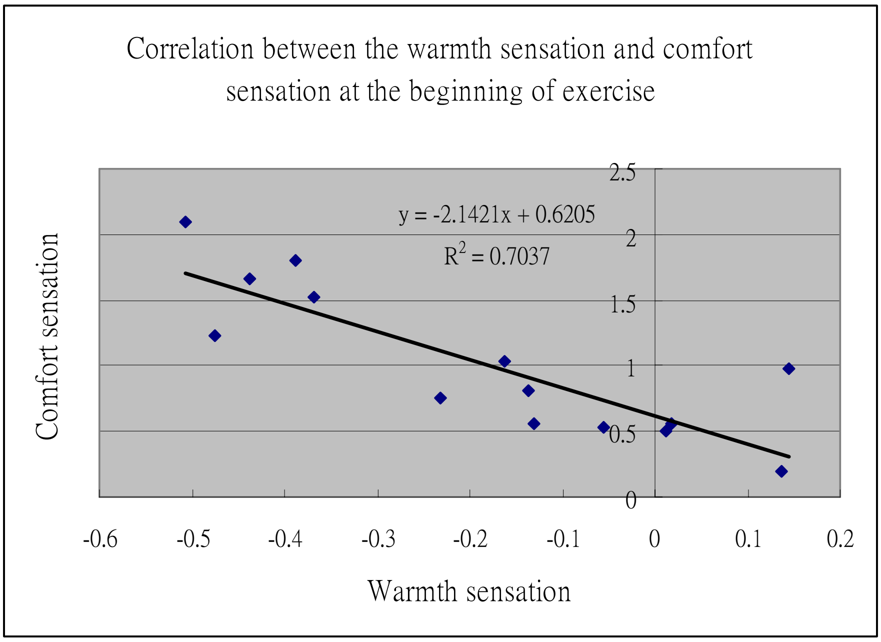


Fig. 5.5 Correlation between warmth and comfort sensations at the beginning of exercise

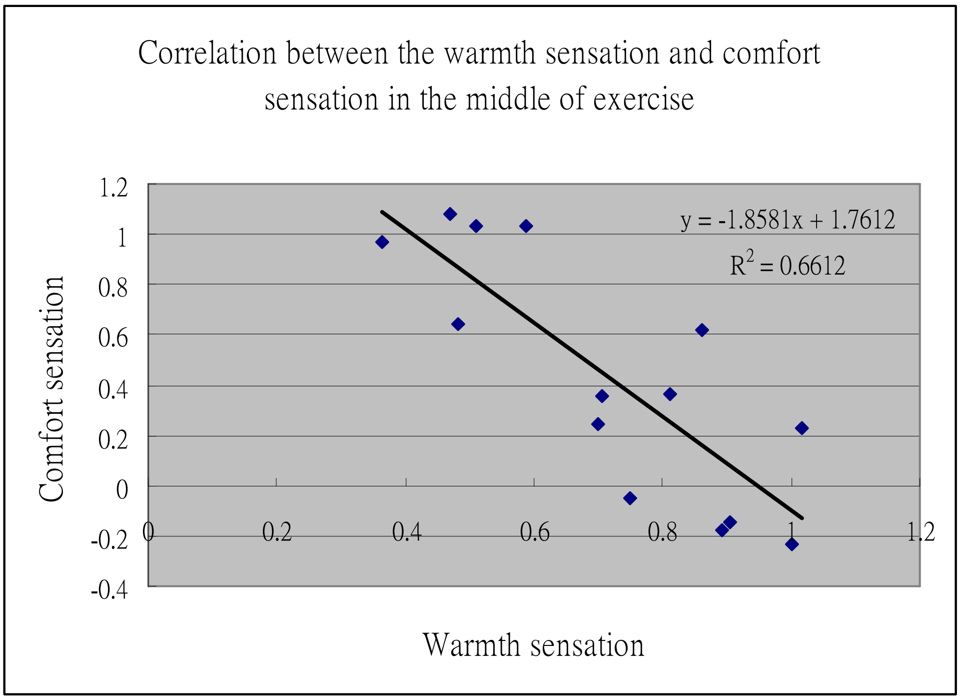


Fig. 5.6 Correlation between warmth and comfort sensations in the middle of exercise

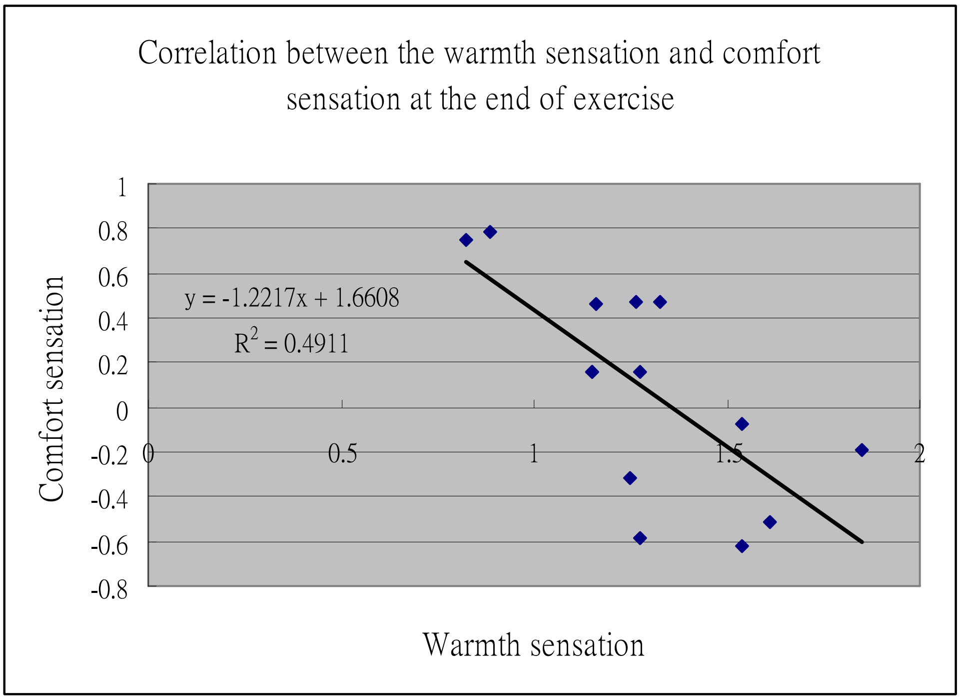


Fig. 5.7 Correlation between warmth and comfort sensations at the end of exercise

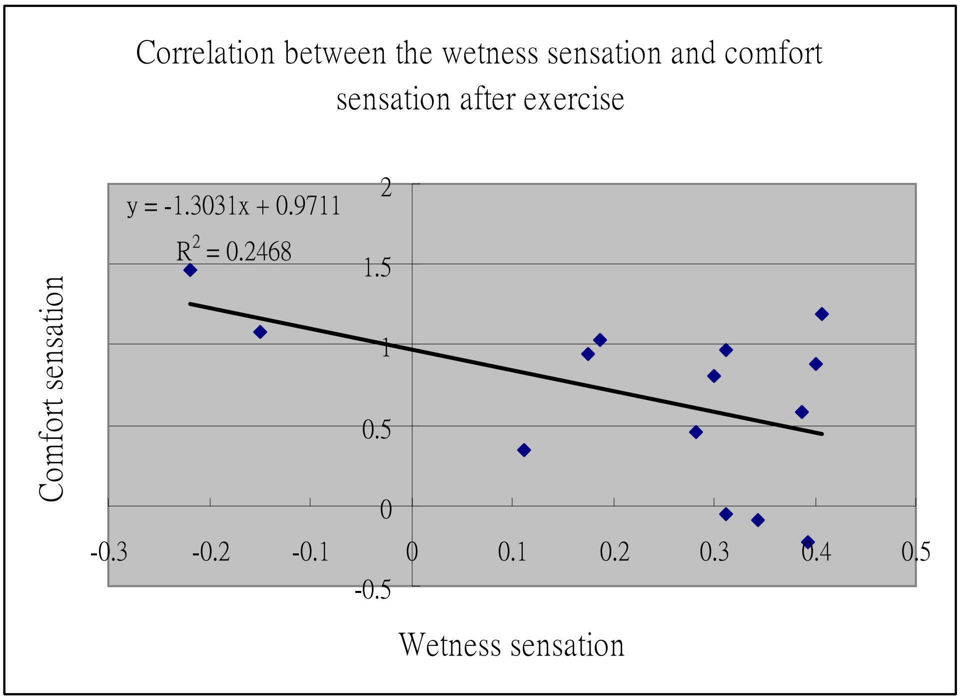


Fig. 5.8 Correlation between skin wetness and comfort sensations after exercise

5.5 Relationships between objective testing results and subjective thermal comfort sensations

By using bivariate correlation tool in SPSS, the summary of the correlation between objective testing results and subjective thermal comfort sensations is listed in Table 5.3 -5.

Both subjective warmth and skin wetness sensations during exercise have a significant positive correlation with the thickness and the thermal insulation properties of the T-shirt fabric. This may be due to a thicker fabric with higher thermal insulation would resist the heat release from the skin to the environment. As a result, the wearer would feel warmer and wetter. A deep analysis of the relationship was carried and explained in the following sections.

Table 5.3 Correlation Coefficient between objective measurements and warmth sensations

		Warm/Cool Sensation at 0 - 5 mins	Warm/Cool Sensation at 10 - 20 mins	Warm/Cool Sensation at 30 mins	Warm/Cool Sensation at 35 - 40 mins
mass per unit area (g/m2)	Pearson Correlation	.344	.261	.068	.361
	Sig. (2-tailed)	.229	.368	.818	.205
	N	14	14	14	14
thickness (mm)	Pearson Correlation	.712(**)	.761(**)	.588(*)	.450
	Sig. (2-tailed)	.004	.002	.027	.106
	N	14	14	14	14
Air Permeability (cm3/s/cm2)	Pearson Correlation	-.090	-.061	-.157	-.401
	Sig. (2-tailed)	.759	.835	.591	.155
	N	14	14	14	14
thermal insulation (clo)	Pearson Correlation	.667(**)	.777(**)	.563(*)	.319
	Sig. (2-tailed)	.009	.001	.036	.266
	N	14	14	14	14
q-max (W/cm2)	Pearson Correlation	-.500	-.577(*)	-.432	-.223
	Sig. (2-tailed)	.068	.031	.123	.444
	N	14	14	14	14
Water Vapor Transmission Rate (g/hr.m2)	Pearson Correlation	-.197	-.252	-.139	-.179
	Sig. (2-tailed)	.499	.385	.636	.540
	N	14	14	14	14
Wicking level (cm) at 5 mins	Pearson Correlation	.187	.127	.053	-.057
	Sig. (2-tailed)	.521	.665	.857	.847
	N	14	14	14	14
Moisture Regain (%)	Pearson Correlation	.233	.096	.149	.177
	Sig. (2-tailed)	.422	.745	.612	.546
	N	14	14	14	14
Thermal insulation by Walter (m2oC/w)	Pearson Correlation	.299	.104	-.094	.230
	Sig. (2-tailed)	.299	.723	.748	.429
	N	14	14	14	14
Water Vapour Resistance by Walter (m2Pa/w)	Pearson Correlation	.538(*)	.671(**)	.511	.474
	Sig. (2-tailed)	.047	.009	.062	.087
	N	14	14	14	14

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5.4 Correlation Coefficient between objective measurements and skin wetness sensations

		Skin Wettness Sensation at 0 - 5 mins	Skin Wettness Sensation at 10 - 20 mins	Skin Wettness Sensation at 30 mins	Skin Wettness Sensation at 35 - 40 mins
mass per unit area (g/m2)	Pearson Correlation	.141	.018	.115	.307
	Sig. (2-tailed)	.631	.952	.696	.285
	N	14	14	14	14
thickness (mm)	Pearson Correlation	.626(*)	.725(**)	.655(*)	.527
	Sig. (2-tailed)	.017	.003	.011	.053
	N	14	14	14	14
Air Permeability (cm3/s/cm2)	Pearson Correlation	-.104	.225	-.128	-.388
	Sig. (2-tailed)	.723	.440	.662	.170
	N	14	14	14	14
thermal insulation (clo)	Pearson Correlation	.590(*)	.804(**)	.598(*)	.369
	Sig. (2-tailed)	.026	.001	.024	.194
	N	14	14	14	14
q-max (W/cm2)	Pearson Correlation	-.529	-.567(*)	-.409	-.240
	Sig. (2-tailed)	.052	.034	.146	.408
	N	14	14	14	14
Water Vapor Transmission Rate (g/hr.m2)	Pearson Correlation	-.082	-.127	-.109	-.185
	Sig. (2-tailed)	.780	.665	.711	.526
	N	14	14	14	14
Wicking level (cm) at 5 mins	Pearson Correlation	.197	.166	.059	-.076
	Sig. (2-tailed)	.500	.571	.842	.796
	N	14	14	14	14
Moisture Regain (%)	Pearson Correlation	.201	.012	.214	.272
	Sig. (2-tailed)	.492	.968	.462	.346
	N	14	14	14	14
Thermal insulation by Walter (m2oC/w)	Pearson Correlation	.266	-.105	.055	.162
	Sig. (2-tailed)	.357	.721	.851	.580
	N	14	14	14	14
Water Vapour Resistance by Walter (m2Pa/w)	Pearson Correlation	.523	.555(*)	.486	.455
	Sig. (2-tailed)	.055	.039	.078	.102
	N	14	14	14	14

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5.5 Correlation Coefficient between objective measurements and overall comfort sensations

		Comfort Sensation at 0 - 5 mins	Comfort Sensation at 10 - 20 mins	Comfort Sensation at 30 mins	Comfort Sensation at 35 - 40 mins
mass per unit area (g/m2)	Pearson Correlation	-.347	-.403	-.564(*)	-.651(*)
	Sig. (2-tailed)	.224	.153	.036	.012
	N	14	14	14	14
thickness (mm)	Pearson Correlation	-.689(**)	-.720(**)	-.759(**)	-.716(**)
	Sig. (2-tailed)	.006	.004	.002	.004
	N	14	14	14	14
Air Permeability (cm3/s/cm2)	Pearson Correlation	.242	.186	.387	.585(*)
	Sig. (2-tailed)	.405	.524	.171	.028
	N	14	14	14	14
thermal insulation (clo)	Pearson Correlation	-.669(**)	-.715(**)	-.610(*)	-.476
	Sig. (2-tailed)	.009	.004	.021	.085
	N	14	14	14	14
q-max (W/cm2)	Pearson Correlation	.467	.501	.323	.195
	Sig. (2-tailed)	.092	.068	.260	.505
	N	14	14	14	14
Water Vapor Transmission Rate (g/hr.m2)	Pearson Correlation	-.059	.047	.328	.401
	Sig. (2-tailed)	.841	.872	.253	.155
	N	14	14	14	14
Wicking level (cm) at 5 mins	Pearson Correlation	-.258	-.134	.006	.214
	Sig. (2-tailed)	.373	.649	.984	.462
	N	14	14	14	14
Moisture Regain (%)	Pearson Correlation	-.328	-.206	-.262	-.435
	Sig. (2-tailed)	.252	.479	.365	.120
	N	14	14	14	14
Thermal insulation by Walter (m2oC/w)	Pearson Correlation	-.362	-.242	-.041	.203
	Sig. (2-tailed)	.203	.404	.890	.487
	N	14	14	14	14
Water Vapour Resistance by Walter (m2Pa/w)	Pearson Correlation	-.300	-.439	-.671(**)	-.655(*)
	Sig. (2-tailed)	.297	.116	.009	.011
	N	14	14	14	14

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

5.5.1 Relationships between the comfort sensations and fabric/clothing properties

By using Principal Component Analysis in SPSS, ten material/garment properties variables could be considered together with different relative predictive powers as some of them are closely related to each other and then formed into four important factors for analysis. These four factors were shown in Table 5.6 and the details are shown in Appendix L (Rotated Component Matrix).

For the first factor is highly related to fabric thermal insulation (r=0.969), thickness (r=0.846) and initial warm/cool feeling (r=-0.799). It therefore represents the initial and steady state heat transfer properties of the fabrics.

The second factor, as can be observed from Table 5.6, is highly related to the water vapor transmission rate (r=-0.907), water vapor resistance of the T-shirt garment (r=0.742) and the mass per unit area of the fabric (r=0.825).. It is believed, therefore, that the second component represents the packing density and the water vapor transmission ability of the fabrics and garments.

The third factor is largely related to the ability of water absorption and fabric air permeability. It is positively related to the moisture regain (r=0.974) and water absorption (r=-0.573) of the fabric material, and inversely dependent on the air permeability (r=-0.69).

The fourth factor is mainly related to the thermal insulation (r=0.936) of the T-shirt garments.

It was observed that the relationship between fabric and garment thermal insulation is very weak, so they are extracted into different groups of factor. As the measurement of sweating manikin is different from the other fabric instruments, it simulates the human wearing condition which includes the heat transfer, sweat absorption and water vapor transmission. The parameter of thermal insulation measured by thermal manikin represents the heat transfer resistance in a wet condition with sweating. Moreover, the moisture or sweat may present in the pores of the fabric or air gaps between the garment and skin, so the thermal insulation value of garment is different from the fabric thermal insulation value.

Table 5.6 Factor analysis of fabric/clothing properties

	Component			
	1	2	3	4
mass per unit area (g/m2)	-.009	.825	.425	.278
thickness (mm)	.846	.364	.343	.017
Air Permeability (cm3/s/cm2)	.230	-.438	-.690	-.004
thermal insulation (clo)	.969	.081	-.121	.064
q-max (W/cm2)	-.799	.278	.399	-.052
Water Vapor Transmission Rate (g/hr.m2)	-.025	-.907	-.070	.300
Wicking level (cm) at 5 mins	.312	-.387	-.573	.329
Moisture Regain (%)	.115	-.014	.974	-.070
Thermal insulation by Walter (m2oC/w)	.068	-.128	-.094	.936
Water Vapour Resistance by Walter (m2Pa/w)	.477	.742	.062	-.372

Table 5.7 Summary of the relationship between four factors and comfort sensations during different stages

	Start	Middle	End	After
Warmth Sensation	Factor 1 (R = 0.717)	Factor 1 + Factor 2 (R = 0.856)	Factor 1 (R = 0.610)	Factor 1 + Factor 2 + Factor 4 (R = 0.548)
Skin Wetness Sensation	Factor 1 (R = 0.681)	Factor 1 (R = 0.804)	Factor 1 (R = 0.645)	Factor 1 + Factor 3 + Factor 2 (R = 0.581)
Overall Comfort Sensation	Factor 1 + Factor 4 (R = 0.820)	Factor 1 (R = 0.716)	Factor 1 + Factor 2 (R = 0.786)	Factor 1 + Factor 2 + Factor 3 (R = 0.838)

From the results shown in Appendix M1-12 and Table 5.7, Factor 1 was the most important factor of the human comfort sensation during the entire process of the exercise. This is understandable, as Factor 1 is highly related to the thickness and thermal insulation of the fabric materials. Thicker and more isolative fabric materials will make the wearer feel warmer at the beginning of the exercise and sweat more during and after exercise.

It can be seen that the fabric thermal insulation (factor 1) is more important to the human warmth sensations instead of garment thermal insulation (factor 4). It may be because the garment thermal insulation measured with a standing manikin is much affected by the air gap, which depends on garment draping and fitting. On the other hand, during the running exercise, the air gap is much reduced, the heat transfer is more dependent on the fabric insulation. As a result, the original fabric thermal insulation corresponds better to the sensations.

The subjective sensations are directly related to the q-max value at the beginning of running exercise. That means the Q-max value detected by Thermal Labo II can be used to express accurately the initial sensations of human including warmth, skin wetness and overall comfort sensations.

At the beginning of the running exercise, thermal comfort sensations are related to Factor 1 and 4 (both representing the heat transfer properties of the fabrics and garments), but not related to Factor 2 and 3, which represent the moisture and liquid transport properties of the fabrics and garments, respectively. Factor 2 becomes an important factor to warmth sensations in the middle of the exercise. During this period, the skin temperature is increasing rapidly and body starts to sweat. A garment with better water vapor transmission performance can result in cooler the wearer human body and more thermal comfortable. So it is important for the warmth sensations in the middle of exercise.

At the end of exercise, Factor 2 is also an important factor of the overall comfort sensation. That means mass per unit area and the water vapor transmission properties of material and garment affect the comfort of human. It may be explained by the packing density of the garment. Higher mass per unit area, higher packing density of a fabric is. As a result, the wearer may feel tighter and uncomfortable.

After exercise, Factor 1 and Factor 2 were the main factors of warmth, skin wetness and overall comfort sensations. The skin temperature arrive the peak and then drop down gradually and the sweating rate is slowing down because of no heat produced by exercise. Thermal conductivity and water vapor transmission are important in this period in order to assist the heat transfer from inner layer to outer layer to release and water vapor transmission from sweats to gas form to release to the environment. So the human will feel more comfortable with lower thermal insulation and higher water vapor transmission rate.

After the exercise, the warmth sensation becomes related to factor 4 which is about the thermal insulation of garment in a wet condition. In this period, the human is standing without exercise and maximum skin temperature is attached with sweating. It slightly simulates the conditions of thermal manikin measurement, so it also affects the human warmth sensation but is not the most important factor.

For the skin wetness and overall comfort sensations, Factor 3 is also a important predictor. As mentioned, Factor 3 is about the water absorption ability and air permeability of fabric. It is important for the release of the sweats from the human skin as water absorption ability can enhance the efficiency of absorbing the water liquid and then transmitting to the environment in order to keep dry. Moreover, higher air permeability of garment can allow more air flowing through the fabric to cool down the body and transmit the sweats. So they are the factors of skin wetness and overall comfort sensations.

5.5.1.1 Comparison of the results of Principle Component Analysis with Multiple Linear Regression Analysis and Bivariate Correlation Analysis

Comparing with another tool in SPSS (Multiple Linear Regression Analysis) for correlating clothing properties and comfort sensations, it is obvious that the reliability of Principle Component Analysis is higher.

A summary of the results by using Multiple Linear Regression Analysis is shown as Table 5.8: (ref. to Appendix N1-12)

Table 5.8 Summary of the relationship between the fabric/clothing properties and comfort sensations by Multiple Linear Regression Analysis

	Start	**Middle**	**End**	**After**
Warmth Sensation	Thickness (R = 0.712)	Thermal Insulation + Water Vapor Resistance (R = 0.855)	Thickness (R = 0.588)	Water Vapor Resistance + Thermal insulation of garment (R = 0.648)
Skin Wetness Sensation	Thickness (R = 0.626)	Thermal Insulation (R = 0.804)	Thickness (R = 0.655)	Thickness (R = 0.527)
Overall Comfort Sensation	Thickness (R = 0.689)	Thickness (R = 0.720)	Thickness (R = 0.759)	Thickness + Air Permeability (R = 0.870)

The results by using Multiple Linear Regression are similar with the results by using Principle Component Analysis. As Multiple Linear Regression is used to find the correlation and form an equation with the properties individually, the relationships between the sensations and properties always include only one or two properties. It showed that lots of sensations are affected mainly by thickness only. However, according to the results of Bivariate Correlation Analysis in SPSS (ref. to table 5.3-5.5), the sensations at these periods are also highly related to the thermal insulation. As mentioned, closed interrelationships have been found at some of properties such as thickness and thermal insulation, so the Principle Component Analysis can group the properties together with relative predictive power before finding the correlation. As a result, the Principle Component Analysis is more reasonable to represent the real situation.

Table 5.9 Summary of the relationship between the fabric/clothing properties and comfort sensations by Bivariate Correlation Analysis

	Start	**Middle**	**End**	**After**
Warmth Sensation	Thickness (0.712)** Thermal insulation (0.667)**	Thermal insulation (0.777)** Thickness (0.761)** Water Vapor Resistance by Walter (0.671)**	Thickness (0.588)* Thermal insulation (0.563)*	Water Vapor Resistance by Walter (0.474) Thickness (0.450)
Skin Wetness Sensation	Thickness (0.626)** Thermal insulation (0.590)**	Thermal Insulation (0.804)** Thickness (0.725)**	Thickness (0.655)* Thermal insulation (0.598)*	Thickness (0.527) Water Vapor Resistance by Walter (0.455)
Overall Comfort Sensation	Thickness (0.698)** Thermal insulation (0.669)**	Thickness (0.720)** Thermal Insulation (0.715)**	Thickness (0.759)** Water Vapor Resistance by Walter (0.671)** Thermal insulation (0.610)* Mass Per unit area (0.564)*	Thickness (0.716)** Water Vapor Resistance by Walter (0.655)* Mass Per unit area (0.651)* Air Permeability (0.585)*

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Moreover, it may be argued that using Bivariate Correlation Analysis (is shown in Table 5.9) replaces Principle Component Analysis as it can find the predictive power of each property individually. However, as our study scope only focuses on different thermal properties and comfort sensations, the clothing properties are similar and related to each other. It's valuable to identify into certain groups to analyze the relationship such as Factor 1 is related to heat transmission ability and Factor 2 is related to water vapor transmission ability.

5.5.2 Relationships between physiological responses and subjective sensations

From Fig. 5.9 – 16, it can be observed that little relationship exists between the physiological responses and subjective sensations during different periods of exercise, although one would expect there should be relationships between the skin temperature and warmth sensation, and the skin humidity and wetness sensation. It may be because the functional effects of the T-shirt samples are similar as they are made by functional fabrics which transfer the moisture and heat effectively. The differences in the skin temperature and skin humidity caused by the fabric samples are much smaller than the possible variations of human subjects at different periods of experiments. The small number of human subjects may also be a problem. Since there were only four subjects in the present investigation, the standard deviations of the average of skin temperature and skin humidity are very high (refer to Table 4.14). The accuracy of the sensors may also not be high enough. The resolution of the temperature and humidity sensors are ±0.3^{o}C and ±5%, respectively. This is difficult to measure the slight differences among 14 samples which had the increase of skin temperature and humidity of about 0.5^{o}C and 8% during the exercise. Furthermore, the thermoregulation of human subjects also dilutes the differences between the different fabric samples.Future experiments should use more accurate sensors or have more human subjects in order to differentiate the small differences in physiological responses.

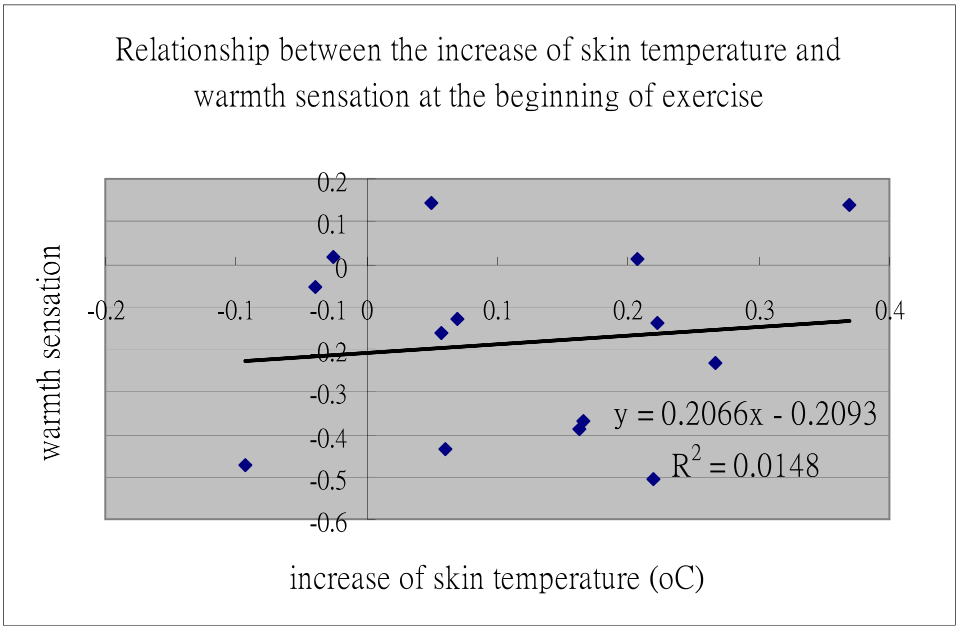


Fig. 5.9 Relationship between the increase of skin temperature and the warmth sensation at the beginning of exercise

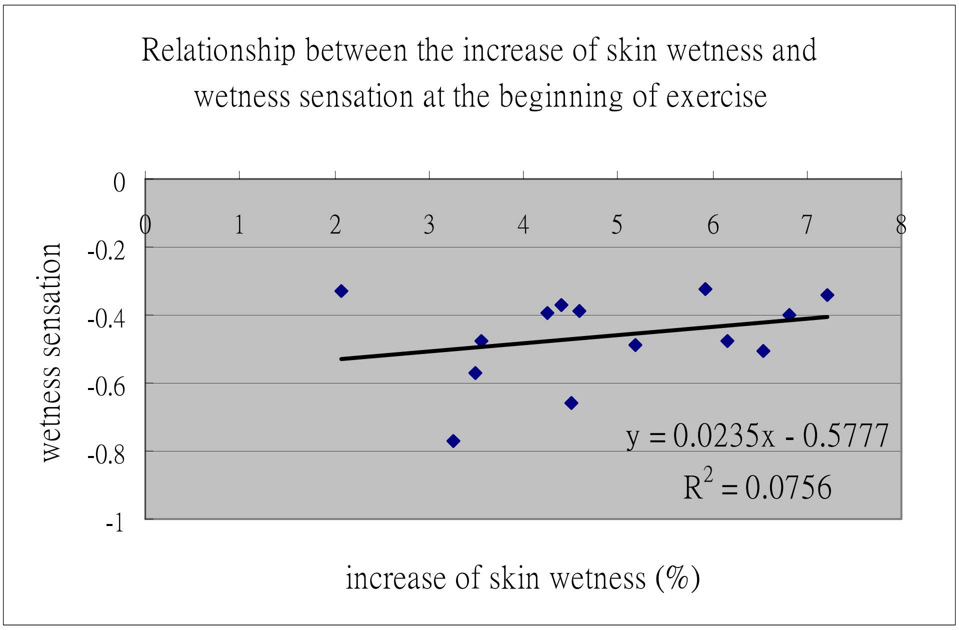


Fig. 5.10 Relationship between the increase of skin humidity and the wetness sensation at the beginning of exercise

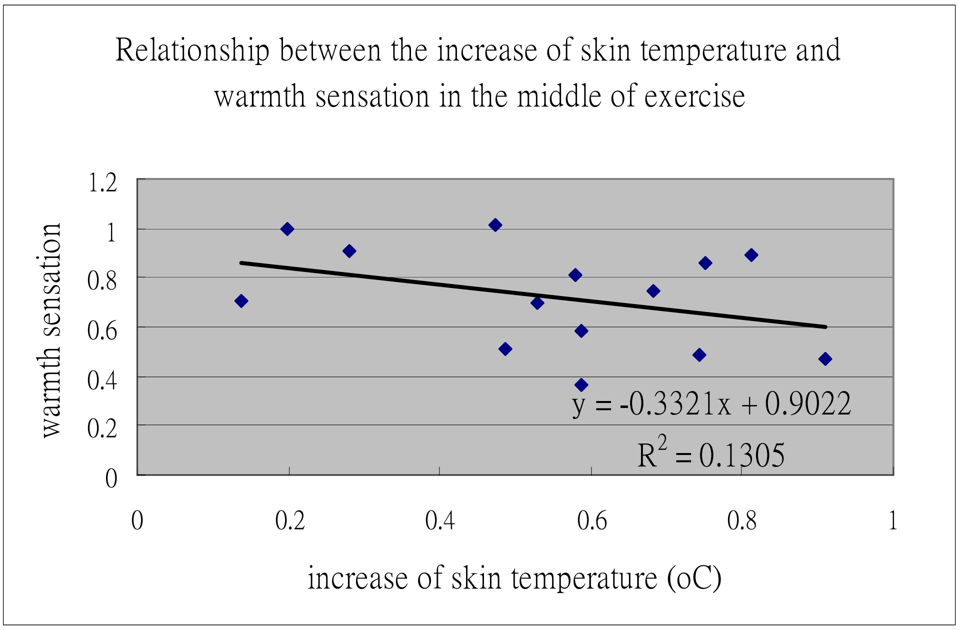


Fig. 5.11 Relationship between the increase of skin temperature and the warmth sensation in the middle of exercise

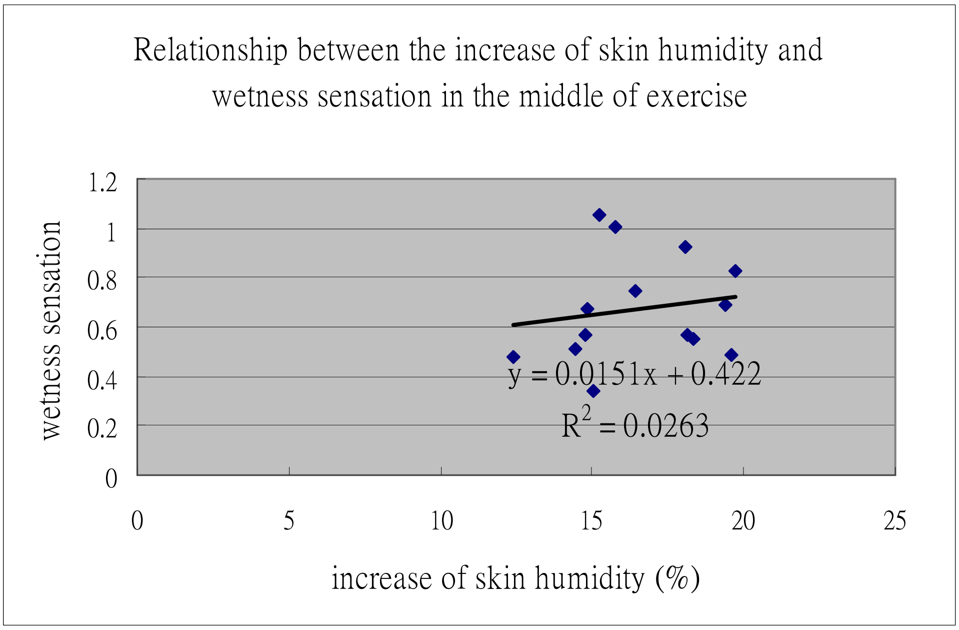


Fig. 5.12 Relationship between the increase of skin humidity and the wetness sensation in the middle of exercise

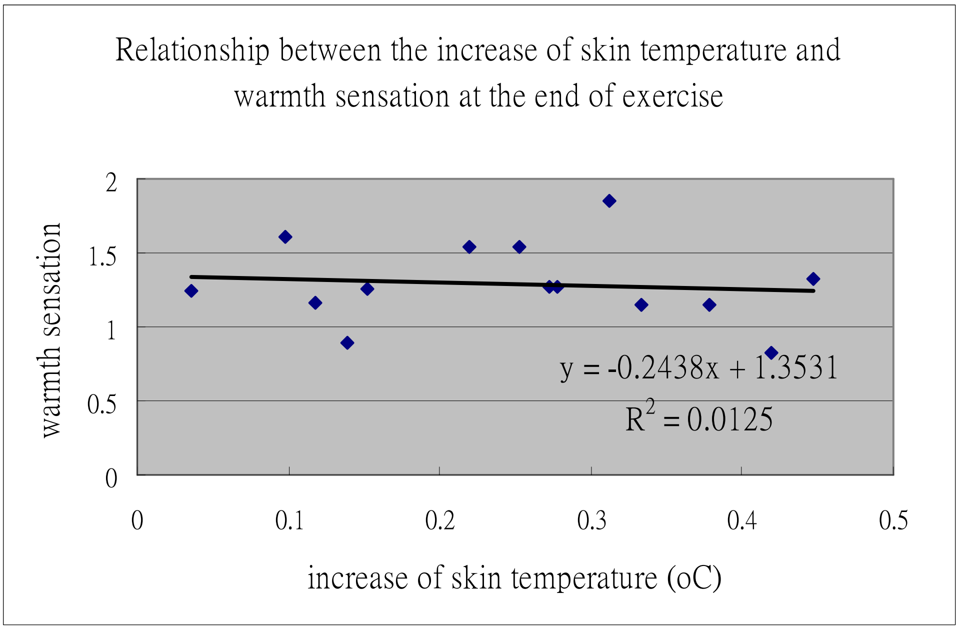


Fig. 5.13 Relationship between the increase of skin temperature and the warmth sensation at the end of exercise

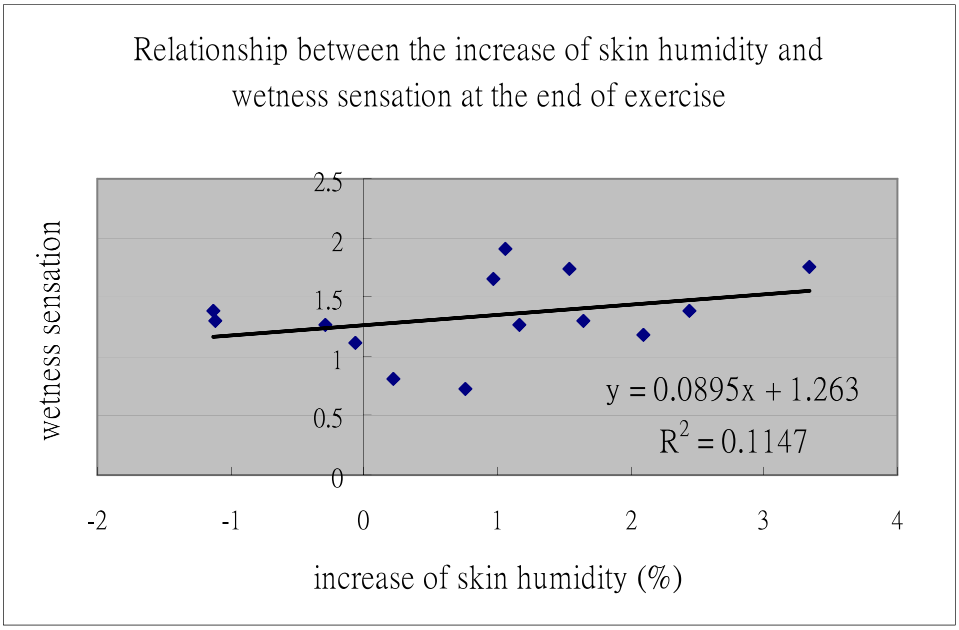


Fig. 5.14 Relationship between the increase of skin humidity and the wetness sensation at the end of exercise

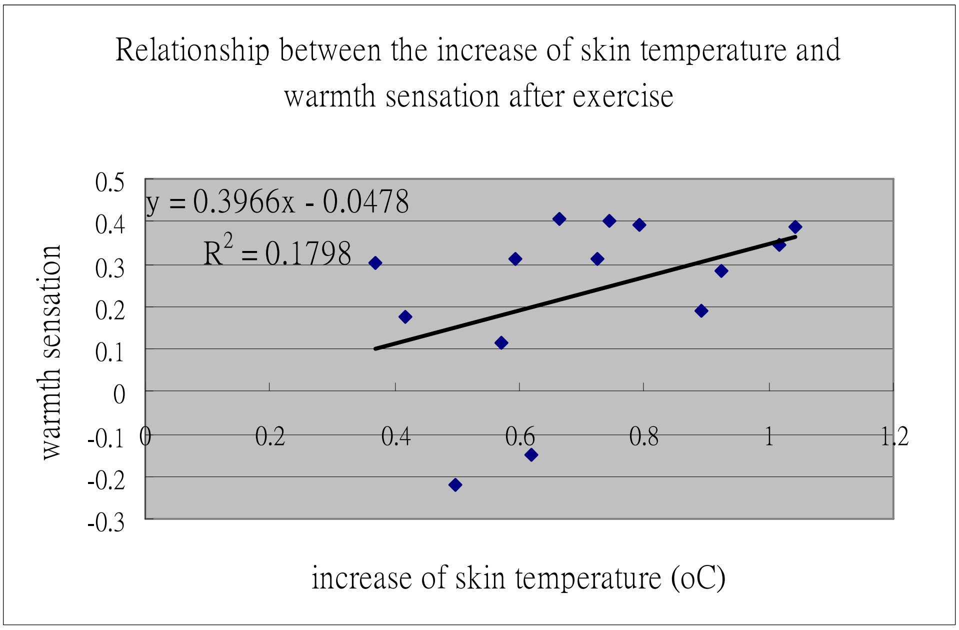


Fig. 5.15 Relationship between the increase of skin temperature and the warmth sensation after exercise

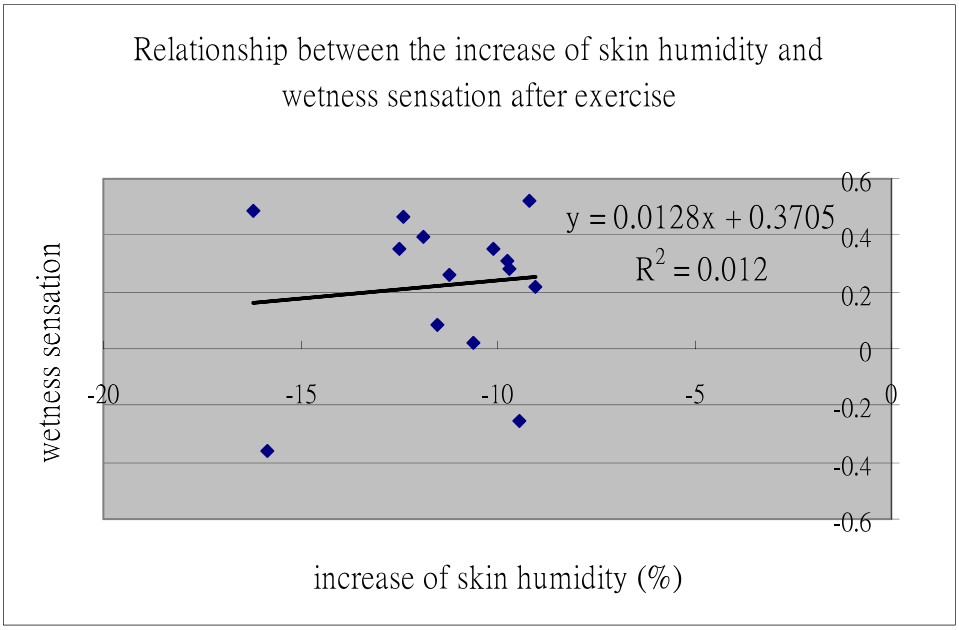


Fig. 5.16 Relationship between the increase of skin humidity and the wetness sensation after exercise

5.6 Summary

Four male subjects were invited to conduct the wearer trials of the T-shirts in the climatic chamber of 21oC and 55% RH. The wearers were asked to perform a cycle of activity including running for 30 minutes at 6.0 km/hr and resting for 10 minutes. The comfort sensations (warmth, skin wetness and overall) at the start, in the middle, at the end and after the running exercise were recorded. Principle Component Analysis was selected to apply to correlate the comfort sensations with the properties of T-shirt fabrics and the measurements of T-shirts from the sweating manikin-Walter as the reliability of it is higher than Multiple Linear Regression and Bivariate Correlation Analysis. It was found that the warm/cool sensation at the start of running exercise is strongly related to thickness, thermal insulation and Q-max of the T-shirt materials; the warm/cool sensation in the middle of running exercise is highly related to thickness, thermal insulation, mass per unit area and water vapor transmission of T-shirt materials; the warm/cool sensation at the end of running exercise is closely related to thickness and thermal insulation; and the warm/cool sensation after running exercise is related to thermal insulation, thickness, water vapor transmission and mass per unit area of T-shirts materials and garment.

On the other hand, it was found that the skin wetness sensation at the beginning, in the middle of and after the running exercise are also closely related to the thermal insulation and thickness of the T-shirt fabrics only; the skin wettedness sensation after the running exercise is highly related to the thickness, thermal insulation, water vapor resistance, mass per unit area and air permeability of T-shirt materials.

With regard to overall comfort, it was found that the thickness and thermal insulation of the fabric materials and T-shirt had great predictive power at the start and in the middle of the running exercise; the overall comfort sensation at the end of running exercise is highly related to thickness, thermal insulation and water vapor tranmssion of T-shirt materials; and after running exercise is closely related to the thickness, thermal insulation, mass per unit area, water vapor resistance and air permeability of the T-shirt fabrics.

CHAPTER 6

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Conclusions

In order to improve thermal comfort of clothing, it's essential to identify or improve the potential factors such as heat and moisture transfer properties. In this thesis, the relationships between heat and moisture transfer properties, physiological responses and comfort sensations were investigated.

Fourteen T-shirts fabrics and garments were used in the study, including interlock and single jersey functional fabrics. Thermal and moisture transfer properties were measured by different objective testing methods and wearer trials were conducted to collect the changes of subjective comfort sensations and human physiological responses at different periods.

By comparing the functional T-shirts, it's difficult to conclude the best performance T-shirt, but it's better to identify their own advantages and disadvantages such as Akwatek® single jersey T-shirt has the best performance in air permeability, water absorption and moisture transmission but the worst in thermal insulation.

With regards to the physical properties of fabrics, relationships exist between different properties. It's found that mass was highly related to air permeability and water vapor transmission and thickness was highly related to the thermal insulation and water vapor resistance. Moreover, four parameters of four moisture transmission tests (ASTM E96 Cup Method, Moisture Transmission Test, Sweating Hot Plate and Sweating Manikin) were closely related to each other.

In addition, the overall comfort sensations was mainly affected by warmth sensation during the exercise, but affected by skin wetness after exercise.

For the relationship between the properties and comfort sensations, by summarizing the results of Principle Component Analysis, Bivariate Regression Analysis and Correlation Coefficient, thickness and thermal insulation were the major predictors of the thermal sensations of human during exercise, and thermal conductivity and water vapor transmission were the main predictors of subjective sensations after exercise. Besides, Q-max value was highly related to subjective warmth, skin wetness and overall comfort sensations at the beginning of running; water vapor transmission performance was another predictor of the warmth sensation in the middle of exercise; mass and water vapor transmission properties were also important factor of overall comfort sensation at the end of exercise; water absorption and air permeability were the factors of skin wetness and overall comfort sensations after exercise.

6.2 Limitations and suggestions for further work

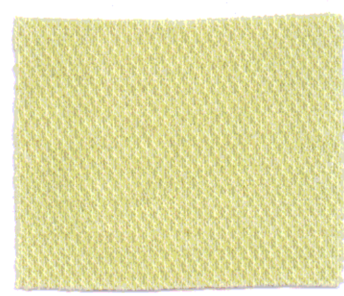
In the market, there are other newly developed functional fabrics or T-shirts such as Adidas® climate-cool T-shirt. Increasing the sample sizes is recommended in the future study. In addition, higher quantities of human subjects in the wearer trials is also recommended to improve the accuracy of the wearer trial results. Since the difference in physiological responses caused by the same style garments made of different fabrics are small, whereas the possible variations of human subjects at different periods of wearer trials tend to be large, accurate temperature and humidity sensors and more human subjects are essential in future investigations of the effect of fabric properties on physiological responses.

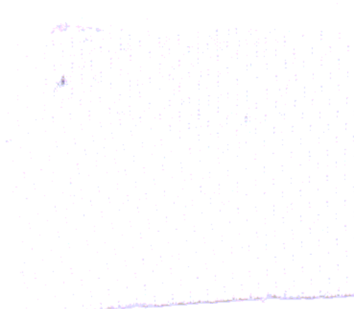
Besides, comfort sensation may be also affected by other properties of fabrics such as mechanical properties, so it's recommended to consider more properties in the future if the time and facilities are possible.

This study is focused on functional T-shirts. The findings may not be applicable to other clothing items such as protective clothing or other sportswear. It's a good idea to conduct similar study on different kinds of garments or clothing items in order to compare the predictors of comfort sensations.

Appendix A
Fabric Samples for Studies

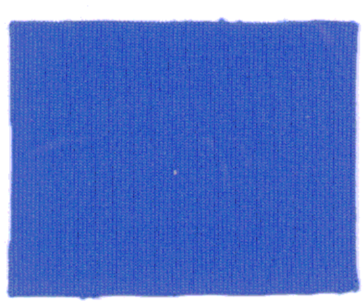
Coolmax®	
	
Single Jersey	Interlock

Tactel®	
	
Single Jersey	Interlock

Akwatek®	
	
Single Jersey	Interlock

Nike® Dri-Fit	
	
Single Jersey	Interlock

TopCool®	
	
Single Jersey	Interlock

Meryl® Nylon	
	
Single Jersey	Interlock

100% Cotton	
	
Single Jersey	Interlock

Appendix B

<u>Garment Samples for Wearer Trial</u>

Coolmax®	
	
Single Jersey Long Sleeves T-shirt	Interlock Long Sleeves T-shirt

Tactel®	
	
Single Jersey Long Sleeves T-shirt	Interlock Long Sleeves T-shirt

Akwatek®	
	
Single Jersey Long Sleeves T-shirt	Interlock Long Sleeves T-shirt

Nike® Dri-Fit

Single Jersey Long Sleeves T-shirt

Interlock Long Sleeves T-shirt

TopCool®

Single Jersey Long Sleeves T-shirt

Interlock Long Sleeves T-shirt

Meryl® Nylon

Single Jersey Long Sleeves T-shirt

Interlock Long Sleeves T-shirt

100% Cotton	
	
Single Jersey Long Sleeves T-shirt	Interlock Long Sleeves T-shirt

Appendix C 男仕服裝試穿測試問卷調查

Questionnaire for Wearer Trials of Men's Wear

我們是香港理工大學紡織及製衣學系的研究人員，現正進行一項“創新服裝產品的開發及評價技術”的研究計劃。是次調查是爲了評估男仕服裝的主觀舒適程度，而你所提供的一切資料均絕對保密及只作研究之用。

We are the research staff of the Institute of Textiles and Clothing in Hong Kong Polytechnic University. We are conducting a research project called "Development of Innovative Apparel Products and Evaluation Technologies". This survey aims at investigating the subjective comfort evaluation for men's wear. The information you provided should be kept secret and used for research purpose only.

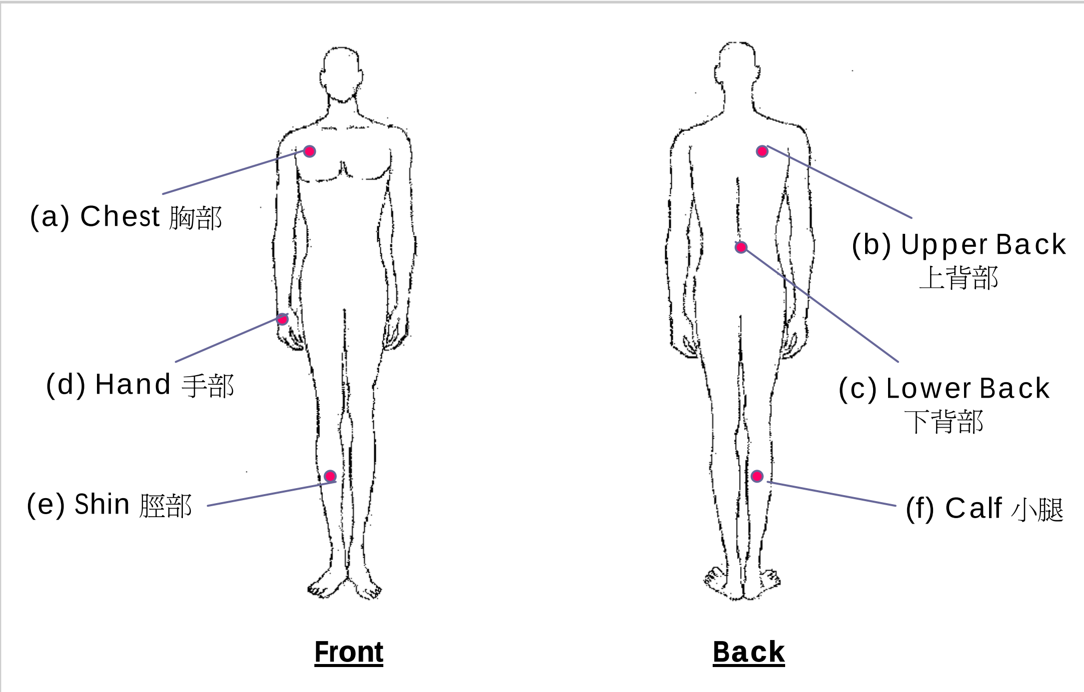
注意：授訪者需清晰地把答案填寫於此問卷上。

P.S.: Interview should write down the answer clearly on this questionnaire.

一・說明 Illustration

下圖列明運動進行時，感應器張貼的部位及授訪者需感應的部位：

The figure below will illustrate what positions the sensors are placed and interviewer needs to feel during testing:



(Staff use only)

檔案編號 File code: ____________________ 服飾編號 Sample no: ________________

授訪者編號 Subject Code: ______________ 服飾尺碼 Wear's Size: ______________

室温 Room Temperature: ________________ 室內濕度 Room Humidity: ____________

服飾重量 Sample's weight: (運動前) Before exercise ______________g (運動後) After exercise ______________g

二・個人資料 Personal Information

a) 姓名：______________________ b) 年齡：______________________
Name Age

c) 身高：______________________(厘米／cm)
Height

d) 體重：(運動前)______________(千克／kg) (運動後)_____________(千克／kg)
Weight (before exercise) (after exercise)

三・舒適度測試 Comfort Evaluation

第一部份：運動進行前
The First Section: Before Exercise

A) 舒適準則 Comfort Criteria

請選出以下不同方面的舒適程度：
Please comment the comfort level on the following aspects:

舒適準則 Comfort Criteria	非常 Extremely	頗 Slightly	適中 Normal	頗 Slightly	非常 Extremely	舒適準則 Comfort Criteria
a) 寬身 Loose Fit						Tight Fit 緊身
(i) 領口 Collar	2	1	0	-1	-2	
(ii) 夾圈 Arm Hole	2	1	0	-1	-2	
(iii) 肩膀 Shoulder	2	1	0	-1	-2	
(iv) 胸口 Chest	2	1	0	-1	-2	
b) 輕 Light	2	1	0	-1	-2	Heavy 重
c) 透氣 Breathable	2	1	0	-1	-2	Air Tight 焗
d) 溫暖 Warm	2	1	0	-1	-2	Cool 涼
e) 柔軟 Soft	2	1	0	-1	-2	Stiff 堅硬
f) 柔軟 Soft	2	1	0	-1	-2	Prickly 刺肉
g) 乾爽 Dry	2	1	0	-1	-2	Clammy 黏貼
h) 平滑 Smooth	2	1	0	-1	-2	Rough 粗糙
i) 光滑 Smooth	2	1	0	-1	-2	Scratchy 痕癢

Other comments:____

____

B) 身體的舒適感應度 Body’s Comfort Sensations

第一部份：運動進行前
The First Section: Before Running

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

第一部份完

第二部份：運動進行5分鐘後

The Second Section: Running after 5 minutes

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

第二部份完

第三部份：運動進行 10 分鐘後
The Third Section: Running after 10 minutes

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

第三部份完

第四部份：運動進行 15 分鐘後

The Forth Section: Running after 15 minutes

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
c) 胸部 Chest					
d) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
c) 胸部 Chest					
d) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

第四部份完

第五部份：運動進行 20 分鐘後

The Fifth Section: Running after 20 minutes

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
e) 胸部 Chest					
f) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
e) 胸部 Chest					
f) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認為該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

第五部份完

第六部份：運動進行 30 分鐘後
The Sixth Section: Running after 30 minutes

A) 身體的舒適感應度 Body’s Comfort Sensations

1. 請劃出現時你身體不同部位的**冷熱**程度：
Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

B) 舒適準則 Comfort Criteria

請選出以下不同方面的舒適程度：
Please comment the comfort level on the following aspects:

舒適準則 Comfort Criteria	非常 Extremely	頗 Slightly	適中 Normal	頗 Slightly	非常 Extremely	舒適準則 Comfort Criteria
a) 寬身 Loose Fit						Tight Fit 緊身
(i) 領口 Collar	2	1	0	-1	-2	
(ii) 夾圈 Arm Hole	2	1	0	-1	-2	
(iii) 肩膀 Shoulder	2	1	0	-1	-2	
(iv) 胸口 Chest	2	1	0	-1	-2	
b) 輕 Light	2	1	0	-1	-2	Heavy 重
c) 透氣 Breathable	2	1	0	-1	-2	Air Tight 焗
d) 溫暖 Warm	2	1	0	-1	-2	Cool 涼
e) Sweat Absorbable 吸汗	2	1	0	-1	-2	Sweat Unabsorbable 不吸汗
f) 柔軟 Soft	2	1	0	-1	-2	Stiff 堅硬
g) 柔軟 Soft	2	1	0	-1	-2	Prickly 刺肉
i) 乾爽 Dry	2	1	0	-1	-2	Clammy 黏貼
j) 平滑 Smooth	2	1	0	-1	-2	Rough 粗糙
k) 光滑 Smooth	2	1	0	-1	-2	Scratchy 痕癢

Other comments:____

第六部份完

第七部份：休息五分鐘後

The Seventh Section: After taking rest for 5 minutes

A) 身體的舒適感應度 Body’s Comfort Sensations

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
a) 胸部 Chest					
b) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

第七部份完

第八部份：休息十分鐘後
The Eighth Section: After taking rest for 10 minutes

A) 身體的舒適感應度 Body’s Comfort Sensations

1. 請劃出現時你身體不同部位的**冷熱**程度：
   Please comment the thermal sensations of different positions of your body:

	涼快 Cool	適中 Normal	頗熱 Slightly Hot	很熱 Very Hot	極熱 Extremely Hot
c) 胸部 Chest					
d) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總冷熱程度 overall**					
	-1	0	1	2	3

2. 請劃出現時你身體不同部位的**乾濕**程度：
   Please comment the humidity sensations of different positions of your body:

	乾爽 Dry	適中 Normal	頗濕 Slightly Damp	很濕 Very Damp	極濕 Extremely Damp
c) 胸部 Chest					
d) 上背部 U. Back					
c) 下背部 L. Back					
d) 手部 Hand					
e) 脛部 Shin					
f) 小腿 Calf					
g) **總乾濕程度 overall**					
	-1	0	1	2	3

3. 總括而言，你認爲該衣服的舒適度是怎樣？
   In a whole view, what do you think of the comfort of this cloth?

極不舒適 Extremely Uncomfortable	很不舒適 Very Uncomfortable	頗不舒適 Slightly Uncomfortable	適　中 Normal	頗舒適 Slightly Comfortable	很舒適 Very Comfortable	極舒適 Extremely Comfortable
-3	-2	-1	0	1	2	3

B) 舒適準則 Comfort Criteria

請選出以下不同方面的舒適程度：
Please comment the comfort level on the following aspects:

舒適準則 Comfort Criteria	非常 Extremely	頗 Slightly	適中 Normal	頗 Slightly	非常 Extremely	舒適準則 Comfort Criteria
a) 寬身 Loose Fit						Tight Fit 緊身
(i) 領口 Collar	2	1	0	-1	-2	
(ii) 夾圈 Arm Hole	2	1	0	-1	-2	
(iii) 肩膀 Shoulder	2	1	0	-1	-2	
(iv) 胸口 Chest	2	1	0	-1	-2	
b) 輕 Light	2	1	0	-1	-2	Heavy 重
c) 透氣 Breathable	2	1	0	-1	-2	Air Tight 焗
d) 溫暖 Warm	2	1	0	-1	-2	Cool 涼
e) Sweat Absorbable 吸汗	2	1	0	-1	-2	Sweat Unabsorbable 不吸汗
f) 柔軟 Soft	2	1	0	-1	-2	Stiff 堅硬
g) 柔軟 Soft	2	1	0	-1	-2	Prickly 刺肉
i) 乾爽 Dry	2	1	0	-1	-2	Clammy 黏貼
j) 平滑 Smooth	2	1	0	-1	-2	Rough 粗糙
k) 光滑 Smooth	2	1	0	-1	-2	Scratchy 痕癢

Other comments:____

全卷完
The End

多謝閣下提供寶貴意見!!
Thank you for your co-operation.

Appendix D Testing Results of Objective Measurements

Table D-1 Testing Results of Mass Per Unit Area (g/m^2)

Sample	Structure	1	2	3	Mean	SD
CoolMax®	Single Jersey	196.74	204.95	196.12	**199.27**	4.928783
	Interlock	151.62	141.9	150.48	**148**	5.313417
Tactel®	Single Jersey	283.44	277.92	291.33	**284.23**	6.739815
	Interlock	188.35	180.26	184.2	**184.27**	4.045454
Akwatek®	Single Jersey	192.37	193.41	194.51	**193.43**	1.07014
	Interlock	123.48	124.72	117.29	**121.83**	3.980339
Nike® Dri-Fit	Single Jersey	190.77	195.31	189.92	**192**	2.897879
	Interlock	131.82	126.75	126.33	**128.3**	3.055634
TopCool®	Single Jersey	202.07	196.78	203.76	**200.87**	3.641442
	Interlock	224.92	228.82	223.15	**225.63**	2.900914
93% Meryl® Nylon	Single Jersey	233.19	230.1	225.81	**229.7**	3.706224
89% Meryl® Nylon	Interlock	209.88	211.72	216.59	**212.73**	3.467146
100% Cotton	Single Jersey	153.08	151.9	147.81	**150.93**	2.765664
	Interlock	237.75	232.86	229.29	**233.3**	4.247128

Table D-2 Testing Results of Thickness (mm)

Sample	Structure	1	2	3	4	5	Mean	SD
CoolMax®	Single Jersey	0.7114	0.6985	0.6962	0.7215	0.6534	**0.6962**	0.02602
	Interlock	0.764	0.761	0.789	0.725	0.821	**0.772**	0.035651
Tactel®	Single Jersey	0.746	0.881	0.913	0.837	0.782	**0.8318**	0.068707
	Interlock	0.947	1.02	0.984	0.897	0.925	**0.9546**	0.048459
Akwatek®	Single Jersey	0.626	0.685	0.675	0.624	0.61	**0.644**	0.033623
	Interlock	0.5693	0.5843	0.5731	0.5281	0.5192	**0.5548**	0.029136
Nike® Dri-Fit	Single Jersey	0.614	0.6452	0.6185	0.602	0.6533	**0.6266**	0.021728
	Interlock	0.7006	0.7134	0.705	0.675	0.669	**0.6926**	0.019475
TopCool®	Single Jersey	0.7389	0.6875	0.712	0.6943	0.6853	**0.7036**	0.022345
	Interlock	0.954	1.042	1.184	1.2	0.975	**1.071**	0.115278
93% Meryl® Nylon	Single Jersey	0.6418	0.587	0.593	0.624	0.6192	**0.613**	0.02272
89% Meryl® Nylon	Interlock	0.6048	0.6315	0.642	0.6057	0.622	**0.6212**	0.016191
100% Cotton	Single Jersey	0.5686	0.5384	0.5517	0.5482	0.5731	**0.556**	0.014494
	Interlock	1.1535	1.1342	1.0825	0.9512	0.9346	**1.0512**	0.102384

Table D-3 Testing Results of ASTM D737-96 Air Permeability Test ($cm^3/s/cm^2$)

Sample	Structure	1	2	3	4	5	Mean	SD
CoolMax®	Single Jersey	95	93	101	88	95	**94.4**	4.669
	Interlock	175	187	194	191	185	**186.4**	7.266
Tactel®	Single Jersey	30	29.9	30.7	30.5	31.8	**30.58**	0.760
	Interlock	168	152	143	159	145	**153.4**	10.310
Akwatek®	Single Jersey	210	205	207	212	204	**207.6**	3.362
	Interlock	251	240	252	240	230	**242.6**	9.099
Nike® Dri-Fit	Single Jersey	67	72	64	68	65	**67.2**	3.114
	Interlock	190	195	201	203	194	**196.6**	5.320
TopCool®	Single Jersey	58	65	63	62	62	**62**	2.550
	Interlock	129	135	144	130	132	**134**	6.042
93% Meryl® Nylon	Single Jersey	47	59	64	63	59	**58.4**	6.768
89% Meryl® Nylon	Interlock	172	163	169	173	155	**166.4**	7.470
100% Cotton	Single Jersey	96	75	86	82	108	**89.4**	12.876
	Interlock	94	98	95	91	99	**95.4**	3.209

Table D-4 Testing Results of Thermal insulation (clo) by KES-FB7 Thermal Labo II

Sample	Structure	1	2	3	4	5	Mean	SD
CoolMax®	Single Jersey	0.00019	0.000199	0.000192	0.000194	0.000186	**0.000192**	4.6063E-06
	Interlock	0.000213	0.000201	0.0002	0.000204	0.000206	**0.000205**	5.24357E-06
Tactel®	Single Jersey	0.000185	0.000179	0.000184	0.000179	0.000179	**0.000181**	2.75714E-06
	Interlock	0.000228	0.000221	0.000233	0.000231	0.000233	**0.000229**	4.99465E-06
Akwatek®	Single Jersey	0.000194	0.000194	0.000193	0.000197	0.000196	**0.000195**	1.60891E-06
	Interlock	0.000174	0.00018	0.00018	0.000181	0.000183	**0.00018**	3.43261E-06
Nike® Dri-Fit	Single Jersey	0.000151	0.000153	0.000151	0.000154	0.000154	**0.000153**	1.67921E-06
	Interlock	0.000216	0.000214	0.000214	0.000209	0.000216	**0.000214**	2.86645E-06
TopCool®	Single Jersey	0.000193	0.000197	0.000196	0.0002	0.000192	**0.000195**	3.17E-06
	Interlock	0.000283	0.000271	0.000269	0.000279	0.000275	**0.000275**	5.62173E-06
93% Meryl® Nylon	Single Jersey	0.000137	0.000141	0.00014	0.000143	0.000144	**0.000141**	2.4786E-06
89% Meryl® Nylon	Interlock	0.000157	0.000152	0.000154	0.000154	0.000158	**0.000155**	2.48379E-06
100% Cotton	Single Jersey	0.000147	0.000143	0.000145	0.000139	0.000147	**0.000144**	3.11445E-06
	Interlock	0.000215	0.000221	0.000221	0.000212	0.000221	**0.000218**	4.5114E-06

Table D-5 Testing Results of Warm/Cool feeling (W/cm^2)

Sample	Structure	1	2	3	4	5	Mean	SD
CoolMax®	Single Jersey	0.105	0.106	0.103	0.098	0.102	**0.1028**	0.0031
	Interlock	0.1	0.102	0.103	0.099	0.099	**0.1006**	0.0018
Tactel®	Single Jersey	0.121	0.126	0.126	0.125	0.124	**0.1244**	0.0021
	Interlock	0.114	0.114	0.109	0.113	0.104	**0.1108**	0.0043
Akwatek®	Single Jersey	0.103	0.105	0.103	0.102	0.103	**0.1032**	0.0011
	Interlock	0.106	0.104	0.11	0.109	0.109	**0.1076**	0.0025
Nike® Dri-Fit	Single Jersey	0.117	0.114	0.119	0.113	0.11	**0.1146**	0.0035
	Interlock	0.097	0.095	0.093	0.095	0.096	**0.0952**	0.0015
TopCool®	Single Jersey	0.106	0.106	0.106	0.103	0.108	**0.1058**	0.0018
	Interlock	0.095	0.094	0.091	0.096	0.1	**0.0952**	0.0033
93% Meryl® Nylon	Single Jersey	0.128	0.126	0.129	0.124	0.128	**0.127**	0.0020
89% Meryl® Nylon	Interlock	0.125	0.127	0.129	0.127	0.127	**0.127**	0.0014
100% Cotton	Single Jersey	0.123	0.122	0.127	0.12	0.118	**0.122**	0.0034
	Interlock	0.106	0.106	0.106	0.107	0.106	**0.1062**	0.0004

Table D-6 Testing Results of ASTM E96 Water Vapor Transmission Test

Weight (g) of cup

Sample	Structure	Times	Day 1	Day 2	Day 3	Day 4	Day 5
CoolMax®	Single Jersey	1	107.0803	105.1068	103.2045	101.4333	99.6008
		2	106.7868	104.7515	102.8422	100.9872	99.1392
	Interlock	1	105.974	103.8783	101.893	99.894	98.0109
		2	106.2125	104.3439	102.4662	100.6643	98.8749
Tactel®	Single Jersey	1	108.1641	106.1861	104.3147	102.489	100.6901
		2	107.7999	105.7747	103.8915	102.0432	100.2101
	Interlock	1	106.7844	104.7879	102.7915	100.9025	99.0548
		2	106.1943	104.2365	102.3157	100.4542	98.596
Akwatek®	Single Jersey	1	106.8288	104.8852	102.9512	100.9944	99.0069
		2	106.5728	104.4001	102.3173	100.2899	98.3072
	Interlock	1	105.3735	103.1547	101.0575	99.0823	97.1251
		2	105.8002	104.2399	101.8322	99.8784	97.9567
Nike® Dri-Fit	Single Jersey	1	106.7222	104.6696	102.679	100.7632	98.8689
		2	106.4303	104.3972	102.4743	100.6181	98.7645
	Interlock	1	105.8169	103.7474	101.7831	99.8572	97.9597
		2	105.3705	103.3114	101.3407	99.413	97.5073
TopCool®	Single Jersey	1	106.8087	104.8162	102.9025	101.0398	99.2163
		2	106.8299	104.6655	102.7256	100.7616	98.8003
	Interlock	1	107.1517	105.1862	103.2911	101.4477	99.6154
		2	107.2226	105.3174	103.4976	101.7284	99.9932
93% Meryl® Nylon	Single Jersey	1	107.5829	105.7636	104.0277	102.3333	100.6449
		2	107.1538	105.2044	103.6078	101.8614	99.9681
89% Meryl® Nylon	Interlock	1	107.1827	105.2791	103.4465	101.7232	100.0388
		2	107.2247	105.2456	103.3141	101.4258	99.5676
100% Cotton	Single Jersey	1	106.215	103.8054	101.5569	99.2822	97.0869
		2	105.8258	103.9143	102.1604	100.4273	98.664
	Interlock	1	107.8645	105.9832	104.2026	102.4918	100.7599
		2	107.0511	104.9777	102.9109	100.9694	99.0425

Table D-7 Water transmission rate (g/hr/m^2) of fabrics by ASTM E96 Test Method

Sample	Structure	Times	Day 2-1	Day 3-2	Day 4-3	Day 5-4	Mean	SD
CoolMax®	Single Jersey	1	-21.3777	-20.6064	-19.1863	-19.8503	**-20.4828**	0.906397
		2	-22.0471	-20.6822	-20.094	-20.0182		
	Interlock	1	-22.7014	-21.5055	-21.6539	-20.3984	**-20.7178**	1.141501
		2	-20.2413	-20.3399	-19.5188	-19.3834		
Tactel®	Single Jersey	1	-21.4264	-20.2717	-19.7766	-19.4863	**-20.3971**	0.853242
		2	-21.9377	-20.3995	-20.0214	-19.8568		
	Interlock	1	-21.6268	-21.6257	-20.4623	-20.0149	**-20.7547**	0.665484
		2	-21.2076	-20.8068	-20.1644	-20.1287		
Akwatek®	Single Jersey	1	-21.0538	-20.9498	-21.1968	-21.5293	**-21.7832**	0.881296
		2	-23.5355	-22.5616	-21.9615	-21.4773		
	Interlock	1	-24.0348	-22.7176	-21.3961	-21.2011	**-21.7892**	2.673932
		2	-16.9017	-26.0811	-21.1643	-20.8165		
Nike® Dri-Fit	Single Jersey	1	-22.2345	-21.5629	-20.7526	-20.5197	**-21.0136**	0.832659
		2	-22.0233	-20.8295	-20.107	-20.0789		
	Interlock	1	-22.4176	-21.278	-20.862	-20.5544	**-21.2861**	0.718547
		2	-22.3049	-21.3473	-20.8815	-20.6432		
TopCool®	Single Jersey	1	-21.5835	-20.7299	-20.1774	-19.7528	**-21.1529**	1.106811
		2	-23.4456	-21.0137	-21.2748	-21.2455		
	Interlock	1	-21.291	-20.5284	-19.9684	-19.8481	**-19.9934**	0.811145
		2	-20.6378	-19.7127	-19.1646	-18.7963		
93% Meryl® Nylon	Single Jersey	1	-19.7073	-18.8039	-18.3543	-18.2894	**-19.1241**	1.254032
		2	-21.1166	-17.2949	-18.9176	-20.5089		
89% Meryl® Nylon	Interlock	1	-20.6205	-19.8514	-18.6674	-18.246	**-20.0412**	1.094742
		2	-21.4383	-20.9227	-20.4547	-20.1287		
100% Cotton	Single Jersey	1	-26.1017	-24.3566	-24.6404	-23.7803	**-22.0573**	2.97582
		2	-20.7061	-18.9989	-18.7736	-19.1007		
	Interlock	1	-20.3789	-19.2881	-18.532	-18.7606	**-20.4639**	1.521244
		2	-22.4598	-22.3883	-21.031	-20.8729		

Table D-8 Testing results of wicking test of fabrics

		Level of water (cm) after 5 mins			
Sample	**Structure**	**1**	**2**	**Mean**	**SD**
CoolMax®	Single Jersey	6	6.05	**6.025**	0.035355
	Interlock	5	4.8	**4.9**	0.141421
Tactel®	Single Jersey	5.3	5.35	**5.325**	0.035355
	Interlock	7	6.8	**6.9**	0.141421
Akwatek®	Single Jersey	7.3	7.6	**7.45**	0.212132
	Interlock	10	10	**10**	0
Nike® Dri-Fit	Single Jersey	7	6.65	**6.825**	0.247487
	Interlock	8.3	8.6	**8.45**	0.212132
TopCool®	Single Jersey	6	6.5	**6.25**	0.353553
	Interlock	5	5.4	**5.2**	0.282843
93% Meryl® Nylon	Single Jersey	0	0	**0**	0
89% Meryl® Nylon	Interlock	0	0	**0**	0
100% Cotton	Single Jersey	0.3	0.4	**0.35**	0.070711
	Interlock	0	0	**0**	0

Table D-9 Testing results of moisture regain (%) of fabrics

Sample	Structure	1	2	3	Mean	SD
CoolMax®	Single Jersey	3.78	3.56	3.81	**3.71**	0.14
	Interlock	4.98	5.17	4.65	**4.94**	0.26
Tactel®	Single Jersey	5.57	5.68	5.81	**5.69**	0.12
	Interlock	5.71	5.46	5.64	**5.60**	0.13
Akwatek®	Single Jersey	1.15	1.29	1.02	**1.15**	0.13
	Interlock	1.64	2.56	1.05	**1.75**	0.76
Nike® Dri-Fit	Single Jersey	4.67	5.18	4.95	**4.93**	0.25
	Interlock	1.06	0.88	0.89	**0.94**	0.10
TopCool®	Single Jersey	4.31	3.96	3.81	**4.03**	0.26
	Interlock	3.65	3.78	3.88	**3.77**	0.12
93% Meryl® Nylon	Single Jersey	3.68	3.04	2.81	**3.18**	0.45
89% Meryl® Nylon	Interlock	3.45	2.96	3.13	**3.18**	0.25
100% Cotton	Single Jersey	7.04	6.76	6.85	**6.88**	0.15
	Interlock	7.39	7.45	7.35	**7.40**	0.05

Table D-10 Testing Results of Thermal Insulation (m2oC/W) by Walter

Sample	Structure	1	2	3	4	5	Mean	SD
CoolMax®	Single Jersey	0.189	0.192	0.195	0.189	0.19	**0.191**	0.00255
	Interlock	0.189	0.19	0.193	0.187	0.19	**0.1898**	0.002168
Tactel®	Single Jersey	0.19	0.191	0.188	0.19	0.188	**0.1894**	0.001342
	Interlock	0.195	0.193	0.191	0.193	0.196	**0.1936**	0.001949
Akwatek®	Single Jersey	0.219	0.22	0.216	0.22	0.223	**0.2196**	0.00251
	Interlock	0.173	0.179	0.184	0.174	0.166	**0.1752**	0.00676
Nike® Dri-Fit	Single Jersey	0.194	0.184	0.183	0.185	0.188	**0.1868**	0.004438
	Interlock	0.175	0.178	0.174	0.186	0.176	**0.1778**	0.004817
TopCool®	Single Jersey	0.188	0.176	0.177	0.181	0.185	**0.1814**	0.005128
	Interlock	0.181	0.175	0.184	0.184	0.171	**0.179**	0.005788
93% Meryl® Nylon	Single Jersey	0.168	0.173	0.172	0.17	0.174	**0.1714**	0.002408
89% Meryl® Nylon	Interlock	0.183	0.182	0.18	0.191	0.176	**0.1824**	0.005505
100% Cotton	Single Jersey	0.186	0.184	0.185	0.181	0.179	**0.183**	0.002915
	Interlock	0.184	0.18	0.179	0.169	0.19	**0.1804**	0.007701

Table D-11 Testing Results of Water Vapor Resistance (m2Pa/W) by Walter

Sample	**Structure**	**1**	**2**	**3**	**4**	**5**	**Mean**	**SD**
CoolMax®	Single Jersey	21.5	21.616	22.32	22.607	22.462	**22.101**	0.507628
	Interlock	21.703	21.609	22.7	22.912	23.263	**22.4374**	0.741857
Tactel®	Single Jersey	22.568	22.38	22.279	22.824	22.862	**22.5826**	0.259698
	Interlock	22.102	22.155	21.855	22.332	22.409	**22.1706**	0.21647
Akwatek®	Single Jersey	21.084	21.193	21.949	21.579	21.644	**21.4898**	0.35191
	Interlock	21.295	21.226	21.618	21.503	21.579	**21.4442**	0.174433
Nike® Dri-Fit	Single Jersey	21.248	21.417	21.5	21.53	21.672	**21.4735**	0.155996
	Interlock	22.581	22.636	22.677	22.411	22.583	**22.5776**	0.10135
TopCool®	Single Jersey	22.158	21.886	22.129	21.87	22.14	**22.0366**	0.482117
	Interlock	22.444	22.921	23.402	23.161	23.346	**23.0558**	0.389744
93% Meryl® Nylon	Single Jersey	23.189	23.306	23.089	23.352	23.316	**23.2504**	0.109015
89% Meryl® Nylon	Interlock	21.232	21.139	22.273	22.549	22.564	**21.9514**	0.709465
100% Cotton	Single Jersey	20.8374	21.0954	20.7074	20.8974	21.5334	**21.0142**	0.322176
	Interlock	23.066	23.461	23.355	23.753	23.403	**23.4076**	0.24578

Table D-12 Testing Results of Water Vapor Resistance (m^2Pa/W) by Sweating Guarded Hot Plate

		Water Vapor Resistance (m^2Pa/W)					Average	SD
	No. of layer	5	4	3	2	1		
CoolMax®	Single Jersey	37.83	34.22	30.96	27.56	24.81	3.255	0.366106
	Interlock	33.62	29.33	26.17	23.75	21.77	2.9625	1.010095
Tactel®	Single Jersey	38.35	33.85	29.67	25.81	22.06	4.0725	0.338366
	Interlock	30.48	28.11	25.86	23.97	22.7	1.945	0.494065
Akwatek®	Single Jersey	30.12	28.35	26.47	24.89	23.54	1.645	0.232451
	Interlock	28.43	26.76	25.22	23.83	22.65	1.445	0.210476
TopCool®	Single Jersey	35.42	31.91	29.03	26.41	24.42	2.75	0.62955
	Interlock	43.75	38.79	34.04	29.5	25.19	4.64	0.278927

Table D-13 Testing Results of Moisture Transmission Rate (g/hm^2) by Moisture Transmission Tester

Sample	CoolMax®				Tactel®				Akwatek®				TopCool®			
Structure	Single Jersey		Interlock		Single Jersey		Interlock		Single Jersey		Interlock		Single jersey		Interlock	
Time	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3	19.6	16.9	18.9	19	16.9	16	15.6	19.1	18.6	20.5	18.6	19	17.5	18.7	13.3	13.5
6	28.5	26.1	27.3	29.2	24.3	23.7	23.2	28.1	28.4	31	28.9	29.1	24.1	27.7	17.1	17.3
9	35.3	33.3	34.3	33.6	30.4	29.8	29.8	35.3	33.9	35.1	34.8	35.2	27.9	34.7	21.1	21.4
12	39.9	35.5	39.5	36.6	35.4	33.8	34.2	40	36.8	38.3	37.7	37.9	31.2	40.5	25.5	25.7
15	43	37.3	42.7	39.5	38.9	37.6	36.4	43.1	39.7	41.3	40.3	40.3	34.2	44.1	30.2	30.4
18	45.1	39	44.8	42	41.5	40.8	38.3	45.2	42.3	43.8	42.8	42.9	36.6	46	34.5	34.7
21	46.9	40.8	46.5	43.9	43.4	42.9	40.3	47.2	44.4	45.5	44.8	44.7	38.6	47.6	38.2	38.4
24	48.2	42.6	48	45.2	44.7	44.1	42.1	48.5	45.9	47.2	46.3	46	40.6	48.8	41	41.4
27	49.3	44.1	49	46.5	45.9	45.3	43.7	49.6	47.4	48.5	47.8	47	42.6	49.7	43.1	43.8
30	50	45.3	49.8	47.6	47.1	47.1	45.1	50.3	48.6	49.4	48.9	47.8	44	50.5	44.5	45.8
33	50.7	46.2	50.4	48.5	48.1	48.3	46.1	51	49.4	50.3	49.7	48.5	45.2	51.2	45.5	47.4
36	51.3	47.3	51	49.2	48.8	49.2	47.3	51.6	50.1	51	50.4	49.3	46.3	51.7	46.7	48.5
39	51.8	48.2	51.5	49.8	49.4	49.6	48.2	52.1	50.8	51.6	51.1	50	47.4	52.2	47.6	49.2
42	52.3	48.9	51.9	50.4	49.9	50.0	49	52.6	51.3	52.1	51.6	50.7	48.2	52.6	48.4	49.7
45	52.7	49.5	52.3	50.8	50.4	50.9	49.6	53.1	51.8	52.7	52.1	51.3	49	52.9	49	50.2
48	53.1	50.1	52.7	51.3	50.8	51.3	50.2	53.5	52.3	53.1	52.6	51.9	49.5	53.2	49.6	50.6
51	53.5	50.6	53.1	51.7	51.2	51.7	50.7	53.9	52.7	53.6	53	52.4	50.2	53.5	50.1	50.9
54	53.8	51	53.5	52.1	51.6	52.1	51.1	54.3	53.1	54	53.4	52.8	50.6	53.8	50.5	51.3
57	54.2	51.5	53.9	52.5	51.9	52.6	51.5	54.7	53.5	54.5	53.8	53.2	51.1	54	51	51.6
60	54.5	51.9	54.2	52.9	52.2	52.9	51.9	55.1	53.9	54.8	54.2	53.6	51.5	54.3	51.3	51.9
63	54.8	52.2	54.5	53.2	52.6	53.1	52.3	55.3	54.3	55.3	54.6	54	51.9	54.5	51.7	52.1
66	55.1	52.5	54.8	53.5	52.9	53.3	52.7	55.6	54.6	55.6	55	54.4	52.3	54.7	52	52.4
69	55.4	53	55.1	53.8	53.1	53.6	53	55.9	55	56	55.3	54.8	52.6	55	52.3	52.6
72	55.7	53.3	55.4	54.2	53.4	53.9	53.4	56.1	55.3	56.3	55.6	56.1	53	55.2	52.6	52.9
75	55.9	53.6	55.7	54.5	53.7	54.2	53.7	56.4	55.6	56.6	55.9	56.4	53.3	55.5	53	53.1
78	56.2	53.9	55.9	54.8	54	54.5	54	56.6	55.9	56.9	56.3	56.7	53.6	55.7	53.2	53.4
81	56.5	54.3	56.2	55	54.2	54.7	54.3	56.8	56.2	57.2	56.5	57	53.9	55.9	53.5	53.7
84	56.7	54.5	56.5	55.3	54.5	54.9	54.6	57	56.7	57.4	56.8	57.3	54.3	56.1	53.7	54
87	56.9	54.8	56.7	55.6	54.7	55.2	54.9	57.2	57	57.6	57	57.5	54.6	56.3	54	54.2
90	57.1	55.1	57	55.8	54.9	55.5	55.2	57.4	57.2	57.8	57.2	57.7	54.9	56.5	54.3	54.5
93	57.3	55.4	57.2	56.1	55.2	55.7	55.5	57.6	57.5	58.1	57.5	57.9	55.1	56.7	54.6	54.7

96	57.5	55.6	57.4	56.3	55.4	55.9	55.8	57.7	57.7	58.2	57.7	58.1	55.4	56.9	54.8	54.9
99	57.7	55.9	57.6	56.5	55.6	56.1	56.1	57.9	57.9	58.4	57.9	58.2	55.7	57.1	55.1	55.1
102	57.9	56.1	57.8	56.8	55.8	56.3	56.3	58.1	58.1	58.6	58.1	58.4	55.9	57.3	55.3	55.4
105	58	56.4	57.9	57	56	56.5	56.5	58.3	58.3	58.7	58.2	58.5	56.2	57.5	55.5	55.6
108	58.1	56.6	58.1	57.2	56.2	56.7	56.8	58.4	58.5	58.8	58.4	58.6	56.4	57.6	55.8	55.8
111	58.2	56.8	58.2	57.3	56.4	56.9	57	58.5	58.6	59	58.6	58.7	56.6	57.8	56	56
114	58.4	57.1	58.4	57.5	56.6	57.1	57.2	58.6	58.8	59.1	58.7	58.8	56.8	57.9	56.2	56.2
117	58.5	57.3	58.5	57.7	56.8	57.2	57.4	58.7	59	59.2	58.8	59	57	58.1	56.4	56.4
120	58.6	57.5	58.6	57.9	57	57.4	57.6	58.8	59.1	59.3	58.9	59.1	57.2	58.2	56.6	56.6
123	58.7	57.7	58.7	58	57.2	57.5	57.8	58.9	59.2	59.4	59.1	59.3	57.4	58.3	56.8	56.8
126	58.8	57.8	58.8	58.2	57.3	57.7	57.9	59	59.3	59.5	59.2	59.4	57.6	58.4	57	57
129	58.9	58	58.9	58.3	57.5	57.8	58.1	59	59.4	59.6	59.2	59.5	57.8	58.5	57.1	57.2
132	59	58.1	59	58.4	57.6	57.9	58.3	59.1	59.5	59.7	59.3	59.6	57.9	58.7	57.3	57.4
135	59.1	58.3	59.1	58.6	57.7	58.1	58.4	59.2	59.6	59.8	59.4	59.7	58.1	58.8	57.5	57.6
138	59.2	58.4	59.2	58.7	57.8	58.2	58.5	59.2	59.6	59.9	59.5	59.8	58.2	58.9	57.6	57.8
141	59.2	58.5	59.3	58.8	58	58.3	58.6	59.3	59.7	59.9	59.6	59.9	58.3	59	57.8	57.9
144	59.3	58.7	59.3	58.9	58.1	58.5	58.7	59.4	59.8	60	59.7	60	58.5	59	57.9	58.1
147	59.4	58.9	59.4	59	58.2	58.6	58.8	59.4	59.8		59.7		58.6	59.1	58	58.3
150	59.4	58.9	59.5	59.1	58.3	58.7	58.9	59.5	59.9		59.8		58.7	59.2	58.2	58.4
153	59.5	59	59.5	59.2	58.4	58.8	59.1	59.5	59.9		59.8		58.8	59.2	58.3	58.6
156	59.6	59.1	59.6	59.3	58.6	58.9	59.2	59.6	60		59.9		58.9	59.3	58.4	58.7
159	59.7	59.2	59.7	59.4	58.7	58.9	59.3	59.6			59.9		59	59.4	58.5	58.8
162	59.7	59.3	59.7	59.5	58.8	59	59.4	59.7			60		59.1	59.4	58.6	58.9
165	59.8	59.4	59.8	59.6	58.8	59	59.5	59.7					59.2	59.5	58.7	59
168	59.8	59.5	59.8	59.6	58.9	59.1	59.5	59.7					59.3	59.5	58.8	59.1
171	59.9	59.6	59.9	59.6	59	59.2	59.6	59.8					59.4	59.6	58.9	59.1
174	59.9	59.7	60	59.7	59.1	59.2	59.7	59.8					59.5	59.6	59	59.2
177	60	59.7		59.8	59.1	59.3	59.7	59.9					59.5	59.7	59.1	59.3
180		59.8		59.8	59.2	59.4	59.8	59.9					59.6	59.7	59.2	59.3
183		59.9		59.9	59.3	59.4	59.9	59.9					59.7	59.8	59.2	59.4
186		59.9		60	59.4	59.5	59.9						59.7	59.8	59.3	59.5
189		60			59.4	59.5	60						59.8	59.9	59.4	59.5
192					59.5	59.6							59.8	59.9	59.4	59.6
195					59.5	59.6							59.9	60	59.5	59.6
198					59.6	59.7							59.9		59.6	59.7
201					59.6	59.7							60		59.6	59.7
204					59.7	59.8									59.7	59.8
207					59.7	59.8									59.7	59.8

210					59.8	59.8									59.8	59.9
213					59.8	59.9									59.8	59.9
216					59.9	59.9									59.9	60
219					59.9	59.9									59.9	
222					60	60									60	
Transmission Rate (g/hm²) (50-60%)	0.0375	0.0388	0.0386	0.0378	0.0307	0.0305	0.0388	0.0358	0.0460	0.0492	0.0434	0.0525	0.0365	0.0330	0.0321	0.0321
Average	0.038181		0.038174		0.030642		0.037328		0.047604		0.047979		0.034777		0.032067	
SD	0.000934		0.000560		0.000127		0.002140		0.002321		0.006434		0.002475		0.000015	

Appendix E Comparison of different objective physical testing results between different T-shirts fabrics by ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
mass per unit area (g/m2)	Between Groups	11370.862	7	1624.409	.668	.697
	Within Groups	14601.370	6	2433.562		
	Total	25972.231	13			
thickness (mm)	Between Groups	.181	7	.026	.751	.645
	Within Groups	.207	6	.034		
	Total	.388	13			
Air Permeability (cm3/s/cm2)	Between Groups	32437.493	7	4633.928	1.190	.424
	Within Groups	23369.056	6	3894.843		
	Total	55806.549	13			
thermal insulation (clo)	Between Groups	.001	7	.000	.801	.615
	Within Groups	.002	6	.000		
	Total	.003	13			
q-max (W/cm2)	Between Groups	.001	7	.000	2.061	.198
	Within Groups	.000	6	.000		
	Total	.002	13			
Water Vapor Transmission Rate (g/hr.m2)	Between Groups	.011	7	.002	2.600	.132
	Within Groups	.004	6	.001		
	Total	.014	13			
Wicking level (cm) at 5 mins	Between Groups	141.794	7	20.256	17.222	.001
	Within Groups	7.057	6	1.176		
	Total	148.851	13			
Moisture Regain (%)	Between Groups	41.886	7	5.984	3.959	.057
	Within Groups	9.070	6	1.512		
	Total	50.956	13			
Thermal insulation by Walter (m2oC/w)	Between Groups	.001	7	.000	.593	.745
	Within Groups	.001	6	.000		
	Total	.002	13			
Water Vapour Resistance by Walter (m2Pa/w)	Between Groups	2.611	7	.373	.541	.780
	Within Groups	4.140	6	.690		
	Total	6.751	13			

Appendix F Results of Subjective Comfort Sensations

F-1) CoolMax® Single Jersey T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.125	-0.075	-0.075	-0.2875	-0.2875	-0.2875	-0.1	-0.6625	-0.6125	-0.625	-0.65	-0.65	-0.6625	-0.65	0.5375
5	0.1375	0.15	0.2	-0.075	-0.1875	-0.1875	0.075	-0.2375	-0.2	-0.1875	-0.3125	-0.3375	-0.3	-0.2625	0.25
10	0.6625	0.725	0.725	0.4	0.3	0.2875	0.6125	0.2875	0.3875	0.3875	-0.0125	-0.075	-0.025	0.2625	-0.0125
15	0.85	0.9125	0.9	0.575	0.4375	0.425	0.8	0.6	0.725	0.7375	0.225	0.3	0.325	0.5625	-0.075
20	1.0375	1.1125	1.15	0.6125	0.6	0.5875	0.8625	0.7	0.9625	0.975	0.2	0.2125	0.2	0.7	-0.15
30	1.1875	1.35	1.3875	0.9125	0.95	0.925	1.225	1.1875	1.375	1.3875	0.625	0.65	0.675	1.1375	-0.3625
35	0.475	0.475	0.375	0.025	0.0375	0.0375	0.25	0.6125	0.675	0.625	0.0625	0.1125	0.1	0.4625	0.2
40	0.325	0.3625	0.3375	-0.1625	-0.075	-0.0625	0.1375	0.3375	0.375	0.35	-0.15	-0.175	-0.1625	0.175	0.3

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0.15	0.15	-0.65	-0.6	-0.6	0	-0.95	-0.85	-0.85	-0.95	-1	-1	-1	0.75
5	0.15	0.25	0.4	-0.45	-0.35	-0.35	0.2	-0.6	-0.45	-0.4	-0.75	-0.7	-0.6	-0.6	0.75
10	0.4	0.65	0.55	-0.5	-0.4	-0.35	0.4	0.35	0.8	0.55	-0.65	-0.6	-0.55	0.1	0.75
15	0.45	0.6	0.6	-0.55	-0.35	-0.35	0.35	0.75	1.15	1.2	-0.6	-0.3	-0.3	0.45	0.7
20	0.65	0.9	0.8	-0.65	-0.45	-0.4	0.15	0.8	1.4	1.4	-0.55	-0.25	-0.25	0.75	0.55
30	0.1	0.55	0.55	-0.5	-0.3	-0.25	0.2	1	1.45	1.5	-0.6	-0.45	-0.35	0.85	0.7
35	-0.05	-0.1	-0.25	-0.8	-0.65	-0.6	-0.35	0.95	1.15	1.1	-0.7	-0.5	-0.5	0.65	0.75
40	0	0.1	0.1	-0.9	-0.6	-0.65	-0.25	0.6	0.75	0.7	-0.6	-0.6	-0.55	0.35	0.85

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0.2	0.25	0.25	0.25	0.25	0.25	0.3	-0.9	-0.85	-0.85	-0.8	-0.75	-0.8	-0.85	0
5	0.5	0.45	0.5	0.45	0.1	0.1	0.35	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.6
10	1.4	1.4	1.45	1.45	0.9	0.85	1.2	-0.1	-0.1	0.15	-0.25	-0.25	-0.25	0.05	-0.8
15	1.25	1.35	1.35	1.4	0.7	0.7	1.2	0.15	0.2	0.2	0.05	0.1	0.1	0.2	-0.5
20	1.2	1.2	1.35	0.85	0.85	0.85	1.05	0.2	0.5	0.5	-0.1	-0.15	-0.15	0.4	-0.6
30	1.55	1.65	1.7	1.1	1.1	1.15	1.6	0.8	0.8	0.85	0.3	0.3	0.3	0.6	-0.85
35	0.8	0.7	0.75	0.15	0.2	0.2	0.5	0.75	0.7	0.7	0.3	0.3	0.3	0.5	-0.5
40	0.95	0.9	0.9	0.2	0.25	0.3	0.5	0.75	0.7	0.65	0.2	0.2	0.2	0.45	-0.3

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.7	-0.7	-0.7	-0.75	-0.8	-0.8	-0.7	-0.8	-0.75	-0.8	-0.85	-0.85	-0.85	-0.75	1.4
5	-0.1	-0.1	-0.1	-0.3	-0.5	-0.5	-0.25	-0.25	-0.25	-0.25	-0.4	-0.55	-0.5	-0.35	0.85
10	0.45	0.5	0.5	0.3	0.25	0.25	0.4	0.5	0.5	0.5	0.5	0.2	0.25	0.45	0.4
15	1	1.05	1.1	0.9	0.8	0.75	0.95	0.9	0.95	0.95	0.8	0.7	0.75	0.9	0.2
20	1.55	1.6	1.65	1.45	1.3	1.15	1.45	1.25	1.45	1.5	0.95	0.75	0.65	1.15	0.4
30	2.1	2.2	2.3	2.05	2	1.8	2.1	1.9	2.2	2.2	1.85	1.75	1.75	2.1	0.2
35	0.95	1.1	0.8	0.55	0.4	0.3	0.7	0.55	0.65	0.55	0.45	0.5	0.4	0.55	0.8
40	0.35	0.45	0.35	0.1	0.1	0.15	0.3	0.05	0.05	0.05	-0.2	-0.3	-0.3	-0.1	0.65

F-2) CoolMax® Interlock T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.3	0.35	0.25	0.25	0.2	0.2	0.25	0.1	0.1	0.2	0.15	0	0.15	0.15	0
15	0.35	0.4	0.45	0.25	0.1	0.1	0.4	0.25	0.15	0.15	0.2	0.05	0.15	0.2	-0.15
20	0.55	0.45	0.5	0.6	0.35	0.55	0.65	0.85	0.85	0.9	0.4	0.3	0.25	0.8	-1
30	0.95	0.95	0.9	1	0.35	0.5	1	0.9	0.95	0.9	0.4	0.3	0.25	1.05	-1.3
35	0.6	0.6	0.6	0.6	0.2	0.2	0.3	0.5	0.5	0.5	0.25	0.25	0.25	0.5	0.8
40	0.2	0.15	0.25	0.25	0.1	0	0.15	0.1	0.1	0.1	0.1	0.1	0.05	0.15	-0.15

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	-0.35	-0.1	0.55	0.05	0.05	0.05	-0.95	-0.6	-0.75	-0.85	-0.95	-0.9	-0.9	1.15
5	0.1	0.2	0.2	0	0.1	0.1	0.15	-0.5	-0.3	-0.35	-0.8	-0.8	-0.8	-0.7	1.1
10	0.3	0.55	0.4	-0.25	0.2	0.15	0.45	-0.35	0.7	0.4	-0.7	-0.75	-0.75	-0.4	0.9
15	0.5	0.75	0.5	-0.4	0.1	0.1	0.4	0	1.1	1.1	-0.75	-0.3	-0.5	0.5	0.85
20	0.55	0.8	0.6	-0.4	-0.2	0.05	0	0.6	1.3	1.3	-0.8	-0.4	-0.5	0.45	1.3
30	-0.25	-0.3	-0.35	-0.45	0.2	0.15	-0.55	0.45	0.85	1.1	-0.7	-0.55	-0.55	0.3	1.5
35	0	0	0	-0.35	0	0	0	0.45	0.45	0.75	-0.65	-0.6	-0.6	0.2	1.6
40	-0.6	-0.25	-0.45	-0.4	-0.1	-0.1	-0.3	0.3	0.7	0.85	-0.9	-0.8	-0.9	-0.5	1.65

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.1	0.1	0.1	-0.2	-0.8	-0.8	-0.15	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	2.45
5	0.05	0.1	0.1	0.05	-0.2	-0.2	-0.15	-0.2	-0.2	-0.2	-0.2	-0.35	-0.35	-0.2	2.25
10	1	1.25	1.3	1.3	0.5	0.5	0.8	1.25	1.35	1.7	0.85	0.15	0.15	0.7	2.1
15	1.05	1.2	1.2	1.2	0.6	0.6	0.8	1.2	1.3	1.3	1	0.25	0.25	0.75	1.7
20	0.85	1.15	1.1	1.15	0.65	0.7	1.1	1.2	1.3	1.3	1.25	0.45	0.45	1.15	2.1
30	1.95	1.85	1.85	1.65	0.75	0.75	1.5	1.85	2.1	2.1	1.7	0.6	0.6	1.4	1.8
35	0.6	0.6	0.4	0	0	0	0	0.3	0.3	0.3	-0.4	-0.4	-0.4	-0.1	2
40	0.45	0.5	0.15	-0.1	-0.25	-0.25	-0.15	0.15	-0.1	-0.15	-0.4	-0.5	-0.5	-0.2	2.2

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.65	-0.2	0.15	0.15	-0.2	-0.2	-0.15	-0.7	-0.7	-0.7	-0.75	-0.75	-0.75	-0.75	0.6
5	1.15	1.35	1.65	1.5	1.25	1.2	1.4	0.75	0.75	0.75	0.55	0.25	0.1	0.85	0.25
10	1.75	1.9	1.85	1.55	1.4	1.25	1.75	0.7	0.95	0.9	0.7	0.3	0.25	0.8	0.15
15	1.8	2.1	2.1	1.65	1.5	1.45	1.65	1.75	2.2	2.2	1.75	1.45	1.55	1.9	-0.3
20	2.2	2.25	2.15	1.85	1.65	1.5	2.1	2.05	2.25	2.25	1.35	1.15	1.15	1.3	-0.2
30	2.75	2.9	2.9	2.45	2.2	2.2	2.7	2.1	2.4	2.4	2.15	2.1	1.9	2.3	-0.15
35	1.1	1.3	1.3	1.1	0.8	0.8	0.9	0.5	0.5	0.5	0.3	0.3	0.1	0.3	0
40	0.6	0.85	0.85	0.6	0.35	0.4	0.6	-0.3	-0.15	-0.15	-0.35	-0.25	-0.25	-0.2	0.15

F-3) Tactel® Single Jersey T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.75	0.75	0.7	0.7	0.75	0.7	0.7	0.55	0.55	0.55	0.55	0.6	0.55	0.6	-0.6
15	1.15	1.2	1.15	1.2	1.15	1.1	1.2	0.95	1	0.95	0.9	0.9	0.9	0.95	-0.85
20	1.5	1.55	1.6	1.6	1.65	1.65	1.6	1.15	1.15	1.15	1.2	1.1	1.2	1.35	-1.1
30	1.7	1.65	1.7	1.7	1.65	1.65	1.7	1.75	1.75	1.85	1.8	1.75	1.65	1.8	-1.6
35	1.1	1.15	1.15	1.1	1.1	1.1	1.1	1.05	1	1	1	0.95	0.95	1	-1.55
40	0.5	0.55	0.6	0.6	0.7	0.65	0.7	0.45	0.4	0.45	0.45	0.45	0.45	0.5	-0.65

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0.1	0.15	-0.4	-0.4	-0.35	-0.05	-0.6	-0.6	-0.55	-0.8	-0.8	-0.8	-0.8	1.85
5	0.3	0.25	0.35	-0.65	-0.25	-0.25	0.05	-0.6	-0.6	-0.55	-0.9	-0.85	-0.8	-0.7	1.1
10	0.45	0.6	0.65	-0.6	-0.3	-0.3	0.25	0.25	0.65	0.5	-0.75	-0.45	-0.45	0.2	0.75
15	0.4	0.6	0.65	-0.65	-0.5	-0.5	0.15	0.7	1	1	-0.75	-0.45	-0.35	0.35	0.85
20	0.65	0.7	0.7	-0.85	-0.5	-0.45	0.3	0.75	1.15	1.3	-0.65	-0.3	-0.3	0.6	0.9
30	0.35	0.6	0.7	-0.55	-0.35	-0.2	0.2	1.05	1.55	1.55	-0.7	-0.45	-0.45	0.85	0.5
35	0	0.15	0.2	-0.75	-0.7	-0.75	-0.3	0.95	1.25	1.2	-0.7	-0.55	-0.55	0.65	1.4
40	0.05	0	0.05	-0.8	-0.6	-0.65	-0.25	0.5	0.6	0.55	-0.75	-0.6	-0.6	-0.05	1.1

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0.2	0.25	0.25	0.25	0.25	0.25	0.25	-0.95	-0.95	-0.95	-0.95	-0.95	-0.9	-0.95	0.05
5	0.35	0.35	0.35	0.35	0.15	0.15	0.3	-0.6	-0.55	-0.6	-0.55	-0.55	-0.5	-0.5	0.05
10	0.2	0.4	0.45	0.2	0.2	0.2	0.4	-0.5	-0.6	-0.55	-0.55	-0.6	-0.6	-0.5	0.05
15	0.2	0.35	0.3	0.2	0.2	0.2	0.2	-0.2	-0.15	-0.2	-0.2	-0.2	-0.3	-0.2	0
20	0.5	0.65	0.65	0.3	0.3	0.3	0.5	0.4	0.45	0.45	0.15	0.1	0.15	0.35	0
30	0.7	0.85	0.85	0.6	0.6	0.6	0.75	0.55	0.55	0.65	0.35	0.4	0.4	0.5	0.05
35	-0.1	-0.1	-0.1	-0.45	-0.45	-0.4	-0.05	-0.3	-0.25	-0.2	-0.35	-0.3	-0.3	-0.15	0
40	0.05	-0.15	-0.15	-0.5	-0.55	-0.55	-0.2	-0.55	-0.55	-0.6	-0.6	-0.6	-0.55	-0.4	0

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0.3	0.4	0.4	0.05	-0.15	-0.6	0.15	-0.35	-0.35	0.3	-0.5	-0.55	-0.6	-0.4	-0.85
5	0.4	0.6	0.55	0.2	0.05	-0.1	0.4	0.3	0.45	0.4	0.1	-0.2	-0.15	0.2	-0.6
10	1.25	1.35	1.45	0.75	0.85	0.7	1.2	1.15	1.35	1.45	1.05	0.9	0.9	1.15	-0.6
15	1.9	2.1	2.25	1.7	1.6	1.55	1.95	2.1	2.35	2.3	1.7	1.5	1.5	1.95	-0.8
20	2.6	2.7	2.7	2.3	1.8	1.6	2.25	2.5	2.45	2.5	1.95	1.7	1.75	2.15	-0.75
30	2.75	2.9	2.95	2.25	1.9	1.75	2.45	2.5	2.65	2.75	2.15	1.95	1.85	2.4	-1.3
35	1.3	1.4	1.55	0.9	0.5	0.45	1.1	0.7	0.8	1.1	0.25	0.35	0.25	0.6	-0.5
40	0.45	0.5	0.5	0.25	0.15	0.1	0.4	0.15	0.2	0.15	-0.3	-0.35	-0.4	-0.05	-0.2

F-4) Tactel® Interlock T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.05	0.05	0.1	0.05	0.05	0.05	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	-0.15
15	0.9	0.9	0.9	0.85	0.9	0.95	1	0.95	0.95	0.9	0.85	0.95	0.95	1	-1
20	1.55	1.65	1.65	1.55	1.65	1.65	1.75	1.9	1.8	1.8	1.8	1.8	1.8	1.75	-1.9
30	2.35	2.4	2.45	2.45	2.45	2.45	2.45	2.4	2.45	2.5	2.65	2.45	2.5	2.55	-2.45
35	1.45	1.35	1.3	1.3	1.3	1.25	1.25	1.15	1.1	1.2	1.2	1.25	1.2	1.3	0.6
40	0.45	0.5	0.4	0.45	0.35	0.45	0.55	0.9	0.75	1.7	1.65	1.55	1.5	1.5	0.85

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.05	-0.1	-0.25	-0.3	-0.25	-0.35	0	-0.95	-0.85	-0.85	-1	-0.95	-0.95	-1	1.25
5	0.3	0.5	0.5	-0.3	-0.2	-0.2	0.15	0.1	0.1	0.15	-0.55	-0.5	-0.45	0.05	1.1
10	0.45	0.7	0.7	-0.45	0.1	0.05	0.4	0.5	0.8	0.6	-0.9	-0.4	-0.7	0.4	0.9
15	0.7	0.85	0.85	-0.4	0.1	0.1	0.5	1	1.1	1.1	-0.75	-0.3	-0.5	0.5	0.85
20	0.85	1.1	1.1	-0.3	0.1	0.1	0.55	0.95	1.2	1.3	-0.85	-0.55	-0.35	0.65	0.8
30	0.55	0.85	0.85	-0.2	0.35	0.45	0.65	1	1.3	1.55	-0.65	0	0	0.85	0.75
35	0	0	0	-0.35	0	0	0	0.45	0.45	0.75	-0.65	-0.2	-0.2	0.3	0.8
40	-0.6	-0.25	-0.45	-0.4	-0.1	-0.1	-0.3	0.2	0.15	0.5	-0.6	-0.7	-0.65	-0.2	0.95

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.1	0.15	0.15	-0.15	-0.7	-0.7	-0.1	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.95	2.15
5	-0.15	-0.15	-0.1	-0.45	-0.5	-0.5	-0.15	-0.1	-0.1	-0.1	-0.1	-0.15	-0.1	-0.15	2.15
10	1.1	1.3	1.3	0.7	0.6	0.4	0.9	1.1	1.15	1.3	0.1	0.05	0.05	0.55	1.9
15	1.15	1.4	1.4	0.6	0.45	0.3	0.8	0.7	1.1	1.3	0.45	0.45	0.45	0.75	1.7
20	1.25	1.35	1.45	0.95	0.9	0.85	1.2	1.3	1.35	1.35	1.35	0.5	0.55	1.25	1.8
30	1.65	2.15	2.15	1.5	0.8	0.8	1.65	1.85	2.15	2.2	1.55	0.75	0.8	1.5	1.3
35	0.4	0.4	0.3	-0.1	-0.15	-0.15	0	0.45	0.45	0.7	-0.3	-0.3	-0.3	0	1.85
40	0.45	0.55	0.35	-0.15	-0.25	-0.25	-0.3	0.3	0.45	0.65	-0.35	-0.45	-0.4	-0.4	2.15

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.9	-0.85	-0.8	-0.55	-0.55	-0.65	-0.7	-0.85	-0.8	-0.8	-0.8	-0.8	-0.85	-0.85	-1.4
5	-0.3	-0.4	-0.35	-0.2	-0.25	-0.2	-0.25	-0.2	-0.3	-0.1	-0.2	-0.2	-0.15	-0.05	-0.8
10	0.6	0.6	0.55	0.45	0.2	0.25	0.45	0.55	0.45	0.45	0.55	0.5	0.55	0.6	-0.35
15	0.95	0.7	0.75	0.5	0.5	0.5	0.7	1.3	1.3	1.15	1.1	0.7	0.6	0.9	-0.2
20	1.5	1.45	1.5	1.25	1.3	1.35	1.4	1.5	1.6	1.55	1.4	1.35	1.35	1.5	0
30	1.55	1.55	1.5	1.4	1.4	1.15	1.4	2.25	2.25	2.3	2.3	1.7	1.5	2.15	0.1
35	0.8	1	1	0.6	0.6	0.6	0.8	0.9	0.9	0.9	0.6	0.6	0.6	0.75	0.2
40	0.5	0.6	0.7	0.25	0.3	0.25	0.5	0.7	0.75	0.75	0.2	0.35	0.25	0.5	0.35

F-5) Akwatek® Single Jersey T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0.2	0.25	0.2	0.2	0.2	0.25	0.25	0.2	0.3	0.25	0.25	0.25	0.3	0.25	-0.4
10	0.5	0.5	0.5	0.5	0.45	0.5	0.55	0.5	0.5	0.5	0.55	0.5	0.55	0.5	-0.65
15	1.45	1.4	1.4	1.4	1.4	1.35	1.5	1.4	1.4	1.4	1.5	1.5	1.5	1.7	-1.25
20	1.8	1.7	1.65	1.65	1.65	1.7	1.75	1.75	1.7	1.7	1.7	1.75	1.75	1.7	-1.65
30	2.2	2.15	2.2	2.2	2.1	2.15	2.25	2.15	2.2	2.25	2.2	2.25	2.25	2.4	-1.85
35	1.4	1.4	1.4	1.35	1.3	1.35	1.4	1.3	1.3	1.4	1.45	1.45	1.45	1.55	-1
40	0.8	0.75	0.7	0.65	0.6	0.65	0.65	0.45	0.55	0.55	0.55	0.55	0.55	0.6	-0.65

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.3	-0.2	-0.2	-0.6	-0.55	-0.5	-0.25	-0.5	-0.5	-0.5	-0.65	-0.6	-0.65	-0.5	1.75
5	-0.05	0.2	0.15	-0.65	-0.6	-0.55	-0.05	0	0	0.05	-0.65	-0.5	-0.35	-0.1	1.7
10	0.45	0.35	0.35	-0.65	-0.55	-0.55	-0.3	0.3	0.3	0.3	-0.6	-0.55	-0.55	-0.15	1.55
15	0.45	0.45	0.5	-0.7	-0.65	-0.65	0.1	0.4	0.5	0.5	-0.5	-0.45	-0.45	0.05	1.5
20	0.6	0.7	0.7	-0.55	-0.45	-0.35	0.4	1	1.45	1.3	-0.5	-0.2	-0.2	0.6	1.65
30	0.6	0.75	0.85	-0.7	-0.5	-0.4	0.2	1.05	1.5	1.5	-0.55	-0.35	-0.3	0.7	1.65
35	0.5	0.45	0.5	-0.4	-0.5	-0.6	0.15	0.65	1	1	-0.55	-0.4	-0.4	0.4	1.5
40	0.55	0.55	0.4	-0.65	-0.55	-0.6	-0.1	0.45	0.75	0.75	-0.75	-0.65	-0.6	0.1	1.55

Subject 3	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	0.45	0.45	0.45	-0.5	-0.5	-0.5	0.05	-0.95	-0.9	-0.95	-0.95	-0.95	-0.95	-0.95	0.6
5	0.8	0.5	0.45	-0.4	-0.4	-0.45	0.15	-0.8	-0.75	-0.8	-0.8	-0.75	-0.8	-0.75	0.5
10	0.65	0.55	0.5	-0.15	-0.1	-0.15	0.3	-0.55	-0.2	-0.25	-0.5	-0.45	-0.5	-0.2	0.45
15	0.7	0.5	0.45	0.1	0.1	0.1	0.4	0.4	0.6	0.6	0.1	0.1	0.1	0.45	0.4
20	0.7	0.6	0.6	0.3	0.25	0.2	0.5	0.55	0.75	0.75	0.4	0.4	0.4	0.6	0.45
30	0.75	0.55	0.55	0.35	0.3	0.4	0.5	0.5	0.75	0.75	0.35	0.4	0.5	0.5	0.6
35	0.5	0.45	0.4	0.1	0.1	0.2	0.4	0.35	0.1	0.1	-0.05	-0.05	-0.1	0.15	0.45
40	-0.1	-0.25	-0.25	-0.4	-0.45	-0.5	-0.2	-0.55	-0.5	-0.5	-0.65	-0.65	-0.65	-0.55	0.55

Subject 4	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.75	-0.75	-0.75	-0.75	-0.8	-0.8	-0.8	-0.75	-0.75	-0.7	-0.7	-0.75	-0.75	-0.7	1.3
5	-0.35	-0.25	-0.15	-0.5	-0.65	-0.6	-0.35	-0.5	-0.5	-0.35	-0.65	-0.55	-0.55	-0.3	1.25
10	0.35	0.55	0.75	0.4	0.15	0.25	0.45	0.45	0.55	0.55	0.4	0.25	0.2	0.45	0.25
15	1.35	1.3	1.3	1.15	1.1	1.1	1.25	1.25	1.25	1.1	0.95	0.9	0.8	1.05	0.35
20	1.5	1.7	1.45	1.3	1.3	1.25	1.5	1.45	1.55	1.45	1.3	1.2	1.15	1.35	-0.1
30	2.4	2.55	2.65	2.2	1.9	1.9	2.35	2.4	2.4	2.65	2.05	1.75	1.65	2.3	-0.3
35	1.25	1.45	1.4	0.55	0.65	0.55	1.1	0.55	0.65	0.65	0.25	0.2	0.15	0.5	0.25
40	-0.05	-0.1	-0.1	-0.3	-0.4	-0.35	-0.15	-0.25	-0.15	-0.05	-0.3	-0.45	-0.45	-0.25	0.9

F-6) Akwatek® Interlock T-shirt

Subject 1	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.7	-0.7	-0.7	-0.7	-0.7	-0.65	-0.65	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.7	1.45
5	-0.8	-0.75	-0.7	-0.75	-0.7	-0.6	-0.8	-0.65	-0.85	-0.75	-0.75	-0.75	-0.7	-0.7	1.4
10	-0.35	-0.3	-0.35	-0.25	-0.25	-0.25	-0.4	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	0.45
15	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.45	0.45	0.5	0.45	0.45	0.45	0.45	-0.45
20	1	1	1	1	1	1	1	0.8	1	1	0.75	0.9	0.95	1	-0.5
30	1.55	1.6	1.55	1.6	1.65	1.75	1.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	-0.7
35	-0.15	-0.15	-0.3	-0.2	-0.2	-0.25	-0.3	-0.2	-0.25	-0.25	-0.25	-0.25	-0.25	-0.35	1.15
40	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.35	-0.4	-0.5	-0.5	-0.5	-0.5	1.25

	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	0	0.05	-0.2	-0.25	-0.25	-0.25	-0.05	-1	-0.95	-0.95	-1	-1	-1	-1	1.65
5	0.1	0.25	0.1	-0.25	-0.25	-0.2	0.05	0.05	0.25	0.25	-0.55	-0.5	-0.45	0.05	1.55
10	0.3	0.5	0.5	-0.35	-0.2	-0.25	0.25	0.3	0.65	0.8	-0.7	-0.6	-0.6	0.4	1.5
15	0.55	0.6	0.7	-0.6	-0.3	-0.2	0.25	0.5	0.75	0.9	-0.75	-0.3	-0.5	0.3	1.5
20	0.55	0.55	0.7	-0.6	-0.5	-0.5	0.3	0.65	1.05	1.3	-0.7	-0.5	-0.5	0.45	1.45
30	0.5	0.45	0.5	-0.85	-0.75	-0.7	0.15	0.45	0.85	1.1	-0.7	-0.55	-0.55	0.3	1.65
35	0	0	-0.2	-0.7	-0.5	-0.5	-0.25	0.45	0.45	0.75	-0.65	-0.5	-0.5	0.1	1.75
40	0.05	0.1	-0.1	-0.85	-0.7	-0.7	-0.1	0.3	0.5	0.55	-0.75	-0.55	-0.55	-0.25	1.75

	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.5	-0.5	-0.5	-0.5	-0.7	-0.8	-0.55	-0.9	-0.9	-0.85	-0.85	-0.85	-0.85	-0.9	2.2
5	-0.35	-0.4	-0.4	-0.6	-0.65	-0.65	-0.25	-0.3	-0.3	-0.4	-0.5	-0.5	-0.5	-0.5	2.2
10	0.35	0.35	0.3	0.15	-0.15	-0.1	-0.3	0.7	0.65	0.6	0.2	0.15	0.15	0.45	2.1
15	0.7	0.75	0.75	0.85	0.4	0.35	0.45	0.3	0.3	0.35	0.3	0.3	0.25	0.05	2.1
20	0.85	0.85	0.85	0.75	0.7	0.6	0.85	0.85	0.9	0.85	0.9	0.35	0.35	0.1	2.1
30	0.8	0.75	0.8	0.25	-0.15	-0.15	0.1	0.45	0.5	0.5	0.15	0.2	0.2	0.25	1.75
35	-0.8	-0.8	-0.8	-0.85	-0.75	-0.85	-0.9	-0.85	-0.85	-0.9	-0.9	-0.9	-0.85	-0.85	2.5
40	-0.9	-0.85	-0.85	-0.9	-0.9	-0.9	-0.7	-0.85	-0.8	-0.8	-0.75	-0.75	-0.75	-0.85	2.25

	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.8	-0.8	-0.8	-0.7	-0.75	-0.75	-0.75	-0.95	-0.95	-0.95	-0.9	-0.9	-0.9	-0.9	1.7
5	-0.5	-0.5	-0.45	-0.5	-0.55	-0.6	-0.5	-0.45	-0.45	-0.55	-0.65	-0.6	-0.6	-0.6	1.1
10	0.05	0	0.05	-0.1	-0.25	-0.3	-0.05	0.2	0.15	0.05	0.1	-0.15	-0.35	-0.05	0.65
15	0.75	0.6	0.65	0.35	0.3	0.35	0.55	0.9	0.65	0.7	0.45	0.5	0.6	0.65	0.4
20	1.15	1.1	1.1	0.75	0.85	0.95	1.05	0.55	0.45	0.35	0.5	0.45	0.45	0.5	0.3
30	1.3	1.15	1.1	1.25	1.25	1.15	1.3	0.9	0.85	0.95	0.9	0.8	0.7	0.85	0.3
35	0.5	0.65	0.8	0.45	0.5	0.5	0.65	0.35	0.25	0.25	0.3	0.25	0.1	0.3	0.35
40	0.3	0.25	0.2	0.4	0.2	0.2	0.25	-0.1	-0.15	-0.1	-0.35	-0.35	-0.25	-0.5	0.75

F-7) Nike® Dri-Fit Single Jersey T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.25	0.25	0.2	0.3	0.3	0.3	0.3	0.2	0.25	0.25	0.3	0.4	0.3	0.3	0
15	1	0.9	1	1	1	1	1	1	1	1	1	1	1.05	1.15	0
20	1.5	1.5	1.45	1.45	1.45	1.5	1.45	1.35	1.45	1.35	1.4	1.35	1.45	1.3	0
30	1.8	1.8	1.75	1.7	1.75	1.9	1.8	1.7	1.75	1.7	1.7	1.7	1.75	1.8	-1.2
35	1.05	1.05	1.1	1.05	1.05	1.05	1	1.1	1.15	1.1	1.15	1.15	1.15	1.15	-0.7
40	0.5	0.5	0.5	0.45	0.4	0.45	0.4	0.45	0.4	0.45	0.45	0.45	0.5	0.5	0.05

	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.75	-0.7	-0.6	-0.85	-0.8	-0.8	-0.75	-0.5	-0.5	-0.5	-0.8	-0.65	-0.75	-0.65	2
5	0.05	0.35	0.3	-0.5	-0.5	-0.5	-0.2	-0.25	0	0.05	-0.6	-0.55	-0.55	-0.3	1.85
10	0.2	0.2	0.25	-0.6	-0.45	-0.45	-0.05	0.2	0.3	0.3	-0.65	-0.55	-0.55	0	1.55
15	0.4	0.6	0.6	-0.5	-0.5	-0.5	0.3	0.55	1.1	1	-0.65	-0.55	-0.5	0.35	1.4
20	0.55	0.55	0.65	-0.6	-0.45	-0.55	0.05	0.8	1.15	1.1	-0.5	-0.5	-0.5	0.6	1.45
30	0.75	0.8	0.9	-0.65	-0.5	-0.5	0.25	1.1	1.4	1.4	-0.55	-0.4	-0.45	0.7	1.6
35	-0.05	0.2	0.15	-0.8	-0.75	-0.8	-0.1	0.65	1.05	1.1	-0.55	-0.4	-0.45	0.55	1.9
40	0	0.05	0.05	-0.55	-0.5	-0.55	-0.3	0.3	0.35	0.35	-0.5	-0.5	-0.55	0	1.35

	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.25	-0.25	-0.25	-0.3	-0.35	-0.3	-0.3	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	1.4
5	-0.85	-0.85	-0.85	-0.85	-0.8	-0.75	-0.75	-0.85	-0.9	-0.85	-0.9	-0.9	-0.9	-0.9	1.45
10	-0.5	-0.4	-0.4	-0.65	-0.6	-0.6	-0.4	-0.55	-0.4	-0.45	-0.6	-0.6	-0.6	-0.45	1.45
15	0.1	0.45	0.5	0	0	0	0.05	-0.2	0.25	0.25	-0.15	-0.15	-0.1	0.05	1.2
20	0.15	0.55	0.55	0.05	0.1	0.1	0.4	0.25	0.65	0.7	0.2	0.15	0.25	0.6	1.25
30	0.85	1	1	0.8	0.8	0.8	1	0.65	0.95	1	0.65	0.65	0.65	0.9	1.2
35	0.05	0.2	0.2	0	0	0.05	0.2	-0.25	0	0	-0.15	-0.15	-0.15	0.05	1.3
40	-0.45	-0.05	-0.05	-0.3	-0.35	-0.4	-0.05	-0.4	-0.1	-0.1	-0.4	-0.35	-0.35	-0.05	1.15

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.5	-0.5	-0.5	-0.6	-0.65	-0.65	-0.5	-0.65	-0.6	-0.65	-0.65	-0.65	-0.65	-0.6	1.25
5	-0.45	-0.35	-0.3	-0.5	-0.65	-0.6	-0.45	-0.35	-0.15	-0.2	-0.45	-0.5	-0.5	-0.4	1.15
10	0.3	0.45	0.6	0.2	0.1	0.1	0.3	0.4	0.6	0.65	0.3	0.1	0.3	0.4	0.45
15	1.05	1.15	1.25	0.85	0.85	0.85	1.05	1.05	1.1	1.2	0.85	0.8	0.8	1.2	0.35
20	1.6	1.8	1.8	1.5	1.45	1.3	1.65	1.5	1.65	1.65	1.1	0.95	0.9	1.35	0.2
30	2.35	2.5	2.6	1.9	1.9	1.9	2.25	2.2	2.55	2.55	2.05	1.9	1.85	2.15	0.3
35	1.2	1.4	1.3	0.65	0.65	0.65	1.05	0.65	0.75	0.65	0.3	0.35	0.3	0.55	0.55
40	0.3	0.35	0.3	0.1	-0.05	-0.05	0.2	0.1	0.2	0.1	-0.3	-0.2	-0.1	0.05	0.8

F-8) Nike® Dri-Fit Interlock T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.5	-0.45
15	0.75	0.7	0.7	0.7	0.7	0.6	0.65	0.55	0.55	0.5	0.45	0.65	0.7	0.7	-0.8
20	2.15	2.1	2.1	2.05	2	2.05	2.1	2.1	2.1	2.2	2.1	2.15	2.1	2.15	-2.3
30	2.75	2.7	2.8	2.7	2.8	2.7	2.8	2.75	2.7	2.9	2.85	2.8	2.85	2.9	-2.75
35	1.45	1.5	1.45	1.45	1.45	1.45	1.45	1.45	1.5	1.5	1.55	1.6	1.6	1.65	-1.3
40	0.95	0.95	0.95	0.95	0.95	0.9	0.9	0.75	0.8	0.8	0.8	0.75	0.7	0.7	-0.35

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.35	-0.1	-0.1	-0.5	-0.5	-0.5	-0.25	-0.95	-0.8	-0.9	-1	-0.95	-0.95	-1	1.4
5	0.25	0.55	0.55	-0.6	-0.55	-0.6	0.15	0.1	0.4	0.55	-0.75	-0.75	-0.65	0.25	1.05
10	0.45	0.75	0.8	-0.7	-0.7	-0.55	0.35	0.5	1.5	1.45	-0.55	-0.55	-0.5	0.65	1
15	0.6	0.7	0.7	-0.6	-0.55	-0.55	0.45	0.6	1.35	1.65	-0.7	-0.4	-0.45	0.6	1.05
20	0.8	1.05	1.1	-0.6	-0.45	-0.35	0.5	0.7	1.6	1.6	-0.6	-0.45	-0.4	0.6	1.25
30	0.6	0.75	0.8	-0.55	-0.4	-0.35	0.35	0.75	1.3	1.45	-0.6	-0.3	-0.25	0.6	1.2
35	0	0.15	0.15	-0.8	-0.65	-0.65	-0.35	0.45	0.7	0.65	-0.7	-0.6	-0.65	0.1	1.3
40	-0.1	-0.05	-0.1	-0.75	-0.65	-0.55	-0.25	0.15	0.4	0.4	-0.75	-0.55	-0.55	-0.25	1.35

Subject 3	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	0.35	0.4	0.45	0.4	-0.15	-0.2	0.1	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.7	1.65
5	0.1	0.2	0.2	-0.1	-0.15	-0.2	0.05	0.1	0.1	0.1	-0.05	-0.1	0	-0.1	1.6
10	1.7	1.7	1.65	0.9	0.85	0.5	1.25	1.25	1.25	1.45	0.25	0.15	0.15	1.05	1.05
15	1.25	1.4	1.5	0.8	0.8	0.6	1.15	1.35	1.3	1.4	0.7	0.75	0.8	1.3	1.05
20	1.45	1.45	1.55	0.9	0.9	0.9	1.3	1.5	1.5	1.5	1.5	0.75	0.75	1.35	1.15
30	1.8	2.2	2.25	1.55	1.1	1.1	1.9	2.15	2.2	2.2	1.65	1.05	1.1	2.05	1.1
35	0.8	0.55	0.55	0	-0.1	-0.1	0.3	0.1	0.8	0.8	-0.3	-0.25	-0.25	0.1	1.5
40	-0.1	-0.1	-0.1	-0.5	-0.55	-0.6	-0.25	0	0.35	0.35	-0.25	-0.3	-0.3	0.2	1.9

Subject 4	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	-0.85	-0.9	-0.9	-0.85	-0.85	-0.85	-0.85	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	1.55
5	-0.5	-0.45	-0.5	-0.65	-0.65	-0.7	-0.5	-0.45	-0.5	-0.55	-0.45	-0.45	-0.45	-0.4	1
10	0.7	0.6	0.65	0.4	0.3	0.45	0.7	0.6	0.6	0.5	0.35	0.4	0.5	0.5	0.05
15	1.15	1.15	1.4	1.05	0.95	0.85	1.15	1.35	1.4	1.5	1.3	1.2	1.05	1.4	-0.05
20	1.85	2.05	2	1.8	1.8	1.8	2.1	1.9	2	1.95	1.7	1.65	1.7	1.85	-0.25
30	2.5	2.5	2.55	2.3	2.2	2.5	2.35	2.15	2.05	2.2	2	1.9	1.95	2.1	-0.3
35	1.2	0.95	1.2	0.9	0.75	0.7	0.95	1.2	1.25	1.25	0.95	0.95	0.9	1	0.15
40	0.4	0.45	0.35	0.3	0.2	0.2	0.35	0.5	0.45	0.4	0.1	0.15	0.25	0.4	0.1

F-9) TopCool® Single Jersey T-shirt

Subject 1	Skin Temperature (°C)							Skin Humidity (%)							Overall Comfort
	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.2	0.25	0.2	0.25	0.25	0.3	0.35	0.15	0.15	0.15	0.1	0.15	0.15	0.15	-0.3
15	1	1.05	1.1	1	1	0.95	1	0.45	0.4	0.4	0.4	0.4	0.4	0.45	-0.8
20	1.15	1.15	1.25	1.2	1.2	1.25	1.3	0.7	0.7	0.7	0.7	0.7	0.75	0.75	-0.75
30	1.15	1.15	1.45	1.45	1.45	1.5	1.45	1	1	1	1.05	1.1	1.1	1.1	-0.95
35	0.85	0.9	0.9	0.85	0.85	0.85	0.85	0.4	0.4	0.4	0.35	0.35	0.45	0.45	-0.45
40	0.5	0.45	0.5	0.45	0.4	0.45	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	-0.2

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.6	-0.35	-0.3	-0.65	-0.7	-0.8	-0.6	-0.45	-0.45	-0.45	-0.9	-0.85	-0.9	-0.75	1.8
5	-0.25	0.1	0	-0.6	-0.55	-0.6	-0.35	-0.4	-0.15	-0.15	-0.85	-0.8	-0.75	-0.5	1.55
10	0.35	0.45	0.5	-0.6	-0.5	-0.45	0.15	0.1	0.4	0.4	-0.8	-0.65	-0.6	-0.05	1.45
15	0.35	0.75	0.85	-0.55	-0.5	-0.5	0.2	0.4	1	1.25	-0.7	-0.5	-0.5	0.25	1.25
20	0.5	0.5	0.5	-0.7	-0.5	-0.45	0.15	0.7	1.3	1.3	-0.6	-0.5	-0.45	0.35	1.35
30	0.5	0.65	0.8	-0.55	-0.3	-0.35	0.25	1	1.45	1.45	-0.6	-0.4	-0.4	0.7	1.35
35	0.3	0.55	0.55	-0.6	-0.6	-0.7	0.05	0.6	0.9	0.9	-0.75	-0.55	-0.6	0.5	1.75
40	-0.05	0.15	0.15	-0.6	-0.55	-0.6	-0.4	0.35	0.55	0.65	-0.75	-0.65	-0.6	0	1.6

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.15	-0.15	-0.2	-0.15	-0.2	-0.2	-0.2	-1.05	-1.05	-1.05	-1.05	-1.05	-1	-1	0.65
5	-0.75	-0.75	-0.75	-0.75	-0.7	-0.7	-0.7	-1	-1	-1	-1	-1	-1	-0.95	0.4
10	-0.4	-0.3	-0.3	-0.6	-0.6	-0.6	-0.4	-0.6	-0.4	-0.4	-0.75	-0.7	-0.75	-0.5	0.65
15	-0.1	0.15	0.15	-0.25	-0.2	-0.25	-0.15	-0.25	-0.2	-0.2	-0.35	-0.25	-0.3	-0.35	0.55
20	0.1	0.45	0.5	0.1	0.1	0.05	0.4	0.1	0.45	0.45	0.05	0.05	0.1	0.4	0.5
30	0.65	0.8	0.9	0.5	0.55	0.6	0.8	0.4	0.6	0.7	0.35	0.4	0.4	0.6	0.45
35	0.15	0.3	0.3	0.05	0.05	0.1	0.1	-0.35	0.2	0.2	-0.25	-0.25	-0.25	-0.05	0.45
40	-0.15	-0.05	-0.05	-0.25	-0.25	-0.35	-0.25	-0.45	-0.45	-0.4	-0.55	-0.55	-0.55	-0.4	0.35

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	0.95
5	0.2	0.25	0.2	0.15	0.25	0.25	0.3	0.05	0.05	0	-0.05	-0.1	-0.15	0	0.7
10	1.1	1.2	1.35	1.05	1.05	1.1	1.25	0.7	0.75	0.85	0.75	0.6	0.55	0.75	0.5
15	1.85	1.95	2.1	1.85	1.85	1.8	1.9	1.85	2.1	2.35	1.75	1.6	1.5	1.7	0.35
20	2.35	2.55	2.6	2.15	2.1	2.1	2.3	2.25	2.45	2.55	1.7	1.45	1.35	1.9	-0.45
30	2.5	2.5	2.4	2.1	1.7	1.35	2.1	2.05	2.4	2.4	1.8	1.7	1.7	2.05	-0.2
35	1.2	1.3	1.4	1.2	0.7	0.7	0.95	0.5	0.6	0.8	0.1	0.1	-0.05	0.35	0.1
40	0.5	0.6	0.55	0.45	0.3	0.3	0.45	-0.3	-0.25	-0.2	-0.45	-0.4	-0.4	-0.35	0.05

F-10) TopCool® Interlock T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.2	0.2	0.2	0.3	0.3	0.25	0.25	0.2	0.2	0.25	0.15	0.25	0.15	0.15	-0.5
15	0.7	0.75	0.7	0.7	0.65	0.65	0.65	0.7	0.6	0.6	0.55	0.6	0.5	0.6	-0.95
20	1.45	1.55	1.5	1.45	1.45	1.4	1.5	1.55	1.5	1.5	1.55	1.5	1.55	1.5	-1.15
30	1.95	1.95	1.95	1.95	1.95	1.95	1.95	2	2	2	1.95	1.95	1.95	1.95	-1.65
35	1.45	1.4	1.3	1.3	1.25	1.3	1.25	1.2	1.15	1.15	1.2	1.15	1.15	1.15	-1
40	0.25	0.3	0.25	0.25	0.25	0.25	0.25	0.25	0.3	0.25	0.3	0.3	0.3	0.3	-0.4

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.15	0.15	0.05	-0.55	-0.25	-0.25	-0.15	-0.95	-0.85	-0.85	-0.95	-0.95	-1	-1	1
5	0.3	0.4	0.45	-0.55	-0.5	-0.45	0.2	0.3	0.5	0.55	-0.65	-0.5	-0.5	0.3	1
10	0.65	0.65	0.6	-0.6	-0.55	-0.45	0.35	0.55	0.9	1	-0.5	-0.5	-0.45	0.6	0.75
15	0.5	0.95	1	-0.5	-0.45	-0.45	0.55	0.75	1.2	1.45	-0.65	-0.35	-0.3	0.8	1
20	0.75	1.05	1.15	-0.45	-0.3	-0.3	0.7	0.75	1.3	1.4	-0.5	-0.3	-0.25	0.7	0.9
30	0.65	1.05	1.2	-0.5	-0.3	-0.25	0.5	0.75	1.45	1.45	-0.6	-0.25	-0.2	0.95	1
35	0.25	0.25	0.25	-0.75	-0.55	-0.5	0.15	0.55	0.8	1	-0.6	-0.6	-0.65	0.5	1.3
40	-0.1	-0.1	-0.1	-0.7	-0.6	-0.6	-0.15	0.2	0.3	0.35	-0.8	-0.75	-0.7	-0.35	1.3

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0.4	0.45	0.55	0.5	0	0	0.25	-0.65	-0.65	-0.65	-0.65	-0.7	-0.7	-0.7	1.65
5	1.2	1.25	1.25	-0.1	-0.1	-0.15	0.85	-0.25	-0.3	-0.35	-0.85	-0.85	-0.85	-0.5	-1.15
10	1.65	1.7	1.85	0.85	0.8	0.75	1.5	0.8	0.65	1.65	0.3	0.25	0.25	1.2	-1.1
15	1.65	1.7	1.8	0.95	0.85	0.85	1.75	1.5	1.5	1.85	0.9	0.9	0.9	1.5	-1.35
20	1.65	1.65	1.8	0.85	0.9	0.9	1.5	1.55	1.6	1.85	1.2	1.15	1.1	1.45	-1.75
30	1.9	1.85	1.95	1.4	1.05	1.05	1.9	2.25	2.35	2.6	1.25	1.25	1.25	2.15	-1.5
35	0.8	0.75	0.85	0	-0.05	-0.05	0.5	0.25	0.65	0.65	-0.25	-0.25	-0.2	0.2	-1.4
40	0	0.05	0.05	-0.45	-0.5	-0.55	-0.2	0.1	0.15	0.15	-0.15	-0.25	-0.2	0.2	-1.3

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.6	-0.55	-0.55	-0.55	-0.55	-0.55	-0.55	-0.75	-0.75	-0.75	-0.75	-0.7	-0.7	-0.7	0.75
5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.55	-0.5	-0.5	-0.55	-0.55	-0.5	-0.5	-0.55	-0.5	0.75
10	0.55	0.5	0.5	0.3	0.35	0.45	0.55	0.55	0.55	0.5	0.45	0.5	0.5	0.55	0.7
15	1	1.1	1	0.75	0.9	0.95	1	1.1	1.3	1.2	1	1.05	1.1	1.2	0.4
20	1.55	1.75	1.75	1.4	1.5	1.55	1.7	1.75	1.85	1.85	1.55	1.7	1.75	1.8	0.3
30	2.1	2.2	2.3	2.1	2	2	2.1	1.95	1.95	2.05	1.75	1.8	1.8	1.9	0.1
35	0.85	0.75	0.75	0.75	0.85	0.85	0.85	0.95	0.9	1	0.85	0.8	0.85	0.95	0.25
40	0.15	0.25	0.15	0.15	0	0	0.1	0.2	0.15	0.2	0	0.05	0.05	0.2	0.5

F-11) 93% Meryl® Nylon Single Jersey T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.5	-0.45	-0.5	-0.5	-0.55	-0.45	-0.4	-0.65	-0.55	-0.55	-0.5	-0.5	-0.55	-0.55	1
5	-0.2	-0.15	-0.1	-0.15	-0.15	-0.15	-0.15	-0.1	-0.2	-0.1	-0.15	-0.1	-0.2	-0.25	0.2
10	0.1	0.15	0.15	0.2	0.15	0.15	0.2	0.2	0.15	0.25	0.1	0.15	0.3	0.25	-0.45
15	1.3	1.25	1.25	1.25	1.25	1.2	1.25	1.35	1.3	1.2	1.2	1.25	1.35	1.4	-0.7
20	1.55	1.6	1.6	1.5	1.45	1.45	1.5	1.55	1.55	1.6	1.55	1.5	1.55	1.5	-1.2
30	1.6	1.65	1.65	1.65	1.5	1.65	1.65	1.7	1.65	1.75	1.8	1.65	1.6	1.65	-1
35	0.9	0.9	0.9	0.85	0.85	0.8	0.85	0.9	0.8	0.85	0.8	0.85	0.75	0.8	-0.5
40	0.5	0.5	0.45	0.35	0.4	0.35	0.35	0.4	0.35	0.35	0.35	0.3	0.35	0.4	-0.25

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.35	-0.1	-0.15	-0.5	-0.5	-0.5	-0.25	-0.4	-0.05	0	-0.65	-0.45	-0.45	-0.35	2.2
5	0.1	0.35	0.35	-0.7	-0.4	-0.3	-0.05	0.2	0.3	0.35	-0.5	-0.45	-0.4	-0.05	2
10	0.5	0.5	0.5	-0.6	-0.45	-0.45	0	0.4	0.35	0.5	-0.65	-0.45	-0.3	0	2
15	0.35	0.3	0.3	-0.45	-0.4	-0.35	0	0.4	0.6	0.75	-0.5	-0.45	-0.4	0.2	2
20	0.75	0.7	0.65	-0.6	-0.35	-0.2	0.25	0.9	1.35	1.5	-0.5	-0.15	-0.25	0.7	1.9
30	1.05	1.2	1.25	-0.45	-0.1	-0.2	0.75	1.4	2	2.05	-0.45	-0.05	-0.05	1.15	1.25
35	0.75	0.9	0.9	-0.7	0	-0.15	0.25	1	1.75	1.85	-0.7	-0.25	-0.15	0.75	1.75
40	0.4	0.3	0.3	-0.7	-0.4	-0.5	0.1	1.05	1.25	1.15	-0.75	-0.55	-0.5	0.6	2.05

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.8	-0.8	-0.75	-0.95	-0.95	-0.9	-0.8	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	-0.95	2.55
5	-0.75	-0.7	-0.7	-0.85	-0.9	-0.85	-0.75	-0.8	-0.85	-0.85	-0.8	-0.8	-0.8	-0.8	2.4
10	-0.6	-0.55	-0.5	-0.8	-0.8	-0.85	-0.55	-0.8	-0.65	-0.6	-0.85	-0.8	-0.8	-0.8	2.2
15	-0.7	-0.45	-0.45	-0.8	-0.8	-0.8	-0.55	-0.7	-0.55	-0.5	-0.75	-0.75	-0.75	-0.55	2.35
20	-0.25	-0.05	-0.1	-0.45	-0.45	-0.45	-0.35	-0.3	-0.15	-0.15	-0.5	-0.5	-0.55	-0.4	2.2
30	-0.3	-0.05	-0.05	-0.45	-0.4	-0.45	-0.25	-0.3	-0.05	-0.05	-0.45	-0.45	-0.45	-0.35	2.2
35	-0.4	-0.25	-0.2	-0.6	-0.6	-0.55	-0.35	-0.5	-0.45	-0.4	-0.55	-0.55	-0.6	-0.5	2.35
40	-0.4	-0.3	-0.25	-0.45	-0.5	-0.5	-0.25	-0.6	-0.5	-0.55	-0.65	-0.75	-0.75	-0.6	2.4

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.45	-0.4	-0.4	-0.7	-0.7	-0.7	-0.5	-0.5	-0.45	-0.45	-0.65	-0.65	-0.65	-0.5	2.3
5	-0.2	-0.15	-0.1	-0.45	-0.45	-0.45	-0.2	-0.4	-0.35	-0.25	-0.55	-0.5	-0.45	-0.35	1.75
10	0.55	0.7	0.8	0.6	0.4	0.4	0.6	0.8	0.85	0.9	0.6	0.5	0.5	0.75	0.85
15	2.2	2.35	2.35	1.9	1.65	1.55	2.1	1.9	1.95	1.85	1.65	1.25	1.25	1.6	0.7
20	2.7	2.75	2.8	2.55	2.55	2.45	2.6	2.15	2.25	2.25	2.05	2.05	2.1	2.2	0.5
30	2.95	2.95	3	2.9	2.7	2.55	2.95	2.95	2.95	2.95	2.45	2.2	2.1	2.65	-1.8
35	1.9	1.8	1.75	1.45	1.4	1.35	1.6	1.8	1.7	1.65	1.45	1.15	1.1	1.15	-0.6
40	0.9	0.95	0.85	0.4	0.45	0.4	0.65	0.5	0.5	0.5	0.15	0.05	0.05	0.25	-0.2

F-12) 89% Meryl® Nylon Interlock T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.7	-0.7	-0.65	-0.75	-0.75	-0.7	-0.8	-0.65	-0.7	-0.65	-0.7	-0.65	-0.7	-0.75	1.5
5	-0.9	-0.9	-0.95	-0.9	-0.9	-0.8	-0.95	-0.9	-0.9	-0.8	-0.85	-0.8	-0.8	-0.75	1.8
10	0	0	0	-0.05	0.1	-0.05	0	0	-0.05	-0.05	-0.05	-0.05	0	0.1	0
15	0.5	0.5	0.5	0.55	0.6	0.55	0.5	0.65	0.55	0.65	0.65	0.7	0.6	0.65	-0.6
20	1.1	1.15	1.25	1.25	1.3	1.2	1.2	1.1	1.2	1.2	1.15	1.05	1.1	1.1	-0.85
30	1.85	1.8	1.8	1.85	2.05	1.85	2	1.75	1.75	1.85	1.85	1.9	1.9	1.9	-1
35	0.4	0.35	0.45	0.4	0.4	0.35	0.4	0.25	0.2	0.2	0.25	0.25	0.3	0.3	-0.35
40	-0.15	-0.1	-0.1	-0.25	-0.15	-0.2	-0.15	-0.1	-0.1	-0.15	-0.2	-0.15	-0.2	-0.25	0

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0.1	0	-0.4	-0.05	-0.05	-0.05	-1	-0.9	-0.9	-1	-1	-1	-1	2.45
5	0.1	0.25	0.35	-0.35	-0.25	-0.25	0.1	0	-0.05	-0.05	-0.75	-0.7	-0.7	-0.5	2.45
10	0.3	0.55	0.6	-0.5	-0.35	-0.3	0.05	0.3	0.5	0.5	-0.75	-0.65	-0.65	0	2.15
15	0.3	0.6	0.75	-0.7	-0.5	-0.5	0.05	0.5	0.85	0.75	-0.75	-0.4	-0.4	0.35	1.85
20	0.4	0.5	0.65	-0.65	-0.45	-0.45	0.05	0.5	0.95	1.05	-0.6	-0.55	-0.5	0.35	1.7
30	0.35	0.5	0.5	-0.8	-0.6	-0.55	0.05	0.5	1	1.15	-0.6	-0.5	-0.45	0.45	2
35	0.1	-0.15	-0.1	-0.7	-0.6	-0.6	-0.1	0.2	0.85	0.9	-0.75	-0.6	-0.6	0.05	1.8
40	0.05	0.05	0.05	-0.7	-0.5	-0.5	-0.4	0.25	0.4	0.5	-0.8	-0.55	-0.5	-0.35	1.9

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.45	-0.45	-0.5	-0.45	-0.8	-0.8	-0.6	-0.9	-0.85	-0.9	-0.9	-0.85	-0.8	-0.9	2.2
5	-0.4	-0.45	-0.45	-0.65	-0.75	-0.75	-0.4	-0.7	-0.7	-0.75	-0.8	-0.75	-0.75	-0.75	2.35
10	0.35	0.4	0.4	0.15	-0.1	-0.05	0.4	0.5	0.5	0.45	0.1	0.05	0.05	0.3	2.25
15	0.85	0.65	0.65	0.6	0.35	0.3	0.5	0.6	0.9	0.9	0.35	0.3	0.25	0.2	2.25
20	0.95	1	1	0.7	0.65	0.6	0.9	0.9	1	1	0.75	0.4	0.45	1.1	2.2
30	1	0.95	0.9	0.2	-0.15	-0.1	0.2	0.5	0.8	0.75	0.15	0.25	0.25	0.3	1.75
35	-0.05	0.05	0.1	-0.35	-0.7	-0.75	-0.55	-0.15	-0.05	-0.05	-0.6	-0.9	-0.9	-0.9	1.9
40	-0.75	-0.65	-0.6	-0.8	-0.75	-0.8	-0.6	-0.8	-0.6	-0.55	-0.65	-0.65	-0.7	-0.8	1.8

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.9	-0.9	-0.9	-0.9	-0.85	-0.85	-0.85	2.3
5	-0.65	-0.65	-0.6	-0.65	-0.65	-0.7	-0.6	-0.6	-0.6	-0.65	-0.75	-0.75	-0.7	-0.65	1.75
10	0.2	0.2	0.25	0.15	-0.05	-0.05	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0.25	0.85
15	0.75	0.8	0.9	0.75	0.65	0.7	0.75	0.85	0.9	0.95	0.8	0.75	0.7	0.85	0.7
20	1.05	1.1	1.1	0.9	0.85	0.95	1.05	0.55	0.55	0.55	0.5	0.4	0.4	0.5	0.5
30	1.25	1.3	1.35	1.25	1.25	1.2	1.3	0.7	0.75	0.8	0.55	0.45	0.45	0.6	0.4
35	0.4	0.5	0.45	0.4	0.3	0.3	0.45	0.25	0.25	0.3	0.25	0.25	0.2	0.25	0.45
40	-0.25	-0.2	-0.2	-0.4	-0.4	-0.35	-0.25	-0.3	-0.35	-0.2	-0.45	-0.4	-0.45	-0.35	1.15

F-13) 100% Cotton Single Jersey T-shirt

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 1	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.1
10	0.5	0.55	0.45	0.5	0.4	0.45	0.45	0.5	0.5	0.55	0.5	0.5	0.55	0.55	-0.55
15	1.25	1.25	1.2	1.25	1.2	1.25	1.25	1.2	1.2	1.25	1.2	1.3	1.3	1.5	-1
20	1.7	1.65	1.65	1.6	1.7	1.7	1.7	1.7	1.7	1.75	1.7	1.7	1.7	1.7	-1.3
30	1.95	2	1.95	1.9	1.9	1.95	2	1.9	1.95	1.95	1.9	1.95	1.9	2	-1.35
35	1.2	1.25	1.25	1.2	1.25	1.2	1.25	1.15	1.2	1.25	1.25	1.3	1.2	1.25	-0.6
40	0.25	0.25	0.3	0.2	0.2	0.25	0.2	0.25	0.25	0.25	0.25	0.25	0.25	0.3	-0.2

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 2	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.7	-0.35	-0.35	-0.85	-0.75	-0.7	-0.65	-0.8	-0.8	-0.85	-0.9	-0.9	-0.95	-0.85	1.75
5	-0.45	-0.3	-0.3	-0.85	-0.8	-0.8	-0.55	-0.5	-0.4	-0.3	-0.7	-0.65	-0.7	-0.6	1.5
10	-0.25	0.1	0.1	-0.6	-0.55	-0.55	-0.25	0.05	0.4	0.35	-0.65	-0.5	-0.5	-0.05	1.3
15	0.3	0.3	0.4	-0.7	-0.6	-0.6	-0.25	0.15	0.4	0.4	-0.6	-0.55	-0.55	-0.2	1.55
20	0.5	0.5	0.55	-0.65	-0.4	-0.35	0.1	0.65	0.95	0.9	-0.65	-0.5	-0.45	0.2	1.6
30	0.5	0.8	0.9	-0.75	-0.6	-0.55	0.25	0.9	1.3	1.25	-0.65	-0.45	-0.35	0.4	1.35
35	0.45	0.45	0.5	-0.7	-0.7	-0.7	0	0.55	0.7	1	-0.65	-0.45	-0.5	0.25	1.55
40	0.1	0.2	0.2	-0.65	-0.7	-0.7	-0.15	0.05	0.45	0.6	-0.55	-0.55	-0.55	0	1.55

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.4	-0.4	-0.45	-0.9	-0.95	-0.9	-0.5	-0.95	-0.9	-0.95	-0.9	-0.95	-0.95	-0.95	1.7
5	-0.9	-0.85	-0.85	-0.95	-0.95	-0.95	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	1.6
10	-0.5	-0.2	-0.15	-0.7	-0.65	-0.65	-0.4	-0.25	-0.1	-0.1	-0.5	-0.5	-0.5	-0.25	1.7
15	0.1	0.3	0.3	0.05	0.05	0	0.1	-0.1	0.3	0.35	-0.1	0	-0.05	0.1	1.5
20	0.45	0.5	0.5	0.15	0.15	0.1	0.4	0.4	0.65	0.65	0.3	0.25	0.3	0.6	1.55
30	0.5	0.65	0.65	0.3	0.25	0.4	0.6	0.5	0.55	0.5	0.3	0.3	0.35	0.55	1.5
35	0.05	0.25	0.2	0	0	0	0.15	0	0.15	0.05	-0.15	-0.1	-0.15	0.15	1.6
40	-0.55	-0.35	-0.3	-0.55	-0.55	-0.6	-0.4	-0.6	-0.45	-0.4	-0.6	-0.6	-0.55	-0.35	1.45

Subject 4	Skin Temperature (°C) Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Skin Humidity (%) Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.7	-0.7	-0.75	-0.85	-0.85	-0.85	-0.75	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.85	1.85
5	-0.5	-0.45	-0.35	-0.65	-0.75	-0.7	-0.55	-0.45	-0.45	-0.45	-0.65	-0.65	-0.65	-0.5	1.5
10	0.15	0.35	0.45	0.35	0.05	0.05	0.2	0.3	0.5	0.5	0.3	0.1	0.15	0.25	0.65
15	1.15	1.2	1.2	0.95	0.95	0.9	1.1	1.15	1.2	1.15	0.95	0.85	0.65	1.05	0.45
20	1.45	1.65	1.55	1.3	1.25	1.2	1.4	1.4	1.5	1.5	1.25	1.1	0.9	1.2	0.3
30	2.2	2.45	2.55	2.1	1.8	1.75	2.2	2.1	2.25	2.5	2.15	1.95	1.65	2.25	0.4
35	0.9	0.85	0.75	0.3	0.3	0.2	0.5	0.5	0.55	0.4	0.15	0.05	0.05	0.35	0.9
40	0.1	0.05	-0.15	-0.2	-0.25	-0.3	-0.15	-0.15	-0.1	-0.1	-0.35	-0.4	-0.35	-0.2	1.3

F-14) 100% Cotton Interlock T-shirt

Subject 1	Skin Temperature (°C) Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Skin Humidity (%) Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.45	0.4	0.45	0.35	0.35	0.5	0.5	0.4	0.45	0.45	0.5	0.4	0.5	0.4	-0.65
15	0.75	0.85	0.85	0.95	0.9	0.75	0.85	0.75	0.7	0.8	0.95	0.8	0.8	0.85	-1.05
20	1.65	1.7	1.7	1.65	1.6	1.6	1.7	1.7	1.7	1.75	1.7	1.75	1.8	1.7	-1.45
30	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-1.85
35	1.3	1.2	1.15	1.15	1.2	1.2	1.1	1.35	1.3	1.4	1.35	1.35	1.35	1.35	-1.5
40	0.35	0.35	0.4	0.4	0.4	0.4	0.4	0.3	0.35	0.35	0.3	0.35	0.45	0.45	-0.7

Subject 2	Skin Temperature (°C) Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Skin Humidity (%) Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	-0.5	0	-0.1	-0.5	-0.65	-0.75	-0.3	-0.75	-0.7	-0.7	-0.95	-0.95	-0.95	-0.85	1.55
5	-0.25	0	0	-0.75	-0.7	-0.65	-0.2	-0.55	0	0.05	-0.8	-0.65	-0.65	-0.5	1.5
10	0.35	0.5	0.45	-0.8	-0.6	-0.55	-0.1	0	0.25	0.25	-0.6	-0.5	-0.5	0.05	1.5
15	0.15	0.65	0.65	-0.6	-0.65	-0.5	0.05	0.25	0.8	1	-0.75	-0.4	-0.3	0.4	1.3
20	0.35	0.85	0.8	-0.85	-0.4	-0.4	0.35	0.7	1.3	1.35	-0.55	-0.5	-0.45	0.8	1
30	0.55	0.85	0.9	-0.5	-0.35	-0.3	0.3	0.75	1.4	1.4	-0.5	-0.4	-0.4	0.75	1.05
35	0.1	0.15	0.15	-0.7	-0.75	-0.75	-0.3	0.5	0.85	0.95	-0.7	-0.55	-0.55	0.25	1.25
40	-0.15	-0.15	-0.15	-0.85	-0.85	-0.85	-0.5	0.15	0.1	0.3	-0.75	-0.65	-0.65	-0.25	1.4

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 3	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0.5	0.5	0.65	0.6	-0.05	-0.05	0.25	-0.7	-0.7	-0.65	-0.65	-0.7	-0.7	-0.7	1
5	0.85	0.8	0.8	-0.15	-0.15	-0.2	0.4	-0.35	-0.4	-0.4	-0.8	-0.8	-0.8	-0.6	0.45
10	1.45	1.45	1.4	0.9	0.85	0.85	1.45	0.35	0.3	0.3	0.05	0.05	0.05	1	0.2
15	1.65	1.6	1.7	0.85	0.85	0.95	1.5	1.55	1.5	1.6	0.95	0.9	0.9	1.45	0.15
20	1.75	1.75	1.8	1.05	1.05	1.05	1.5	1.5	1.45	1.7	1.15	1.15	1.1	1.45	0.4
30	1.9	1.85	2.05	1.1	1.2	1.15	1.85	1.8	1.8	2.1	1.2	1.2	1.3	1.9	0.15
35	1.15	1.2	1.65	0.05	0.05	0.05	0.85	0.45	0.8	0.85	-0.2	-0.15	-0.15	0.3	-0.35
40	0.1	0.2	0.3	-0.4	-0.45	-0.5	0.1	0.15	0.15	0.25	-0.15	-0.25	-0.15	0.3	0.25

	Skin Temperature (°C)							Skin Humidity (%)							
Subject 4	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Chest	Upper back	Lower back	Hand	Shin	Calf	Overall	Overall Comfort
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.45	0.4	0.45	0.35	0.35	0.5	0.5	0.4	0.45	0.45	0.5	0.4	0.5	0.4	-0.65
15	0.75	0.85	0.85	0.95	0.9	0.75	0.85	0.75	0.7	0.8	0.95	0.8	0.8	0.85	-1.05
20	1.65	1.7	1.7	1.65	1.6	1.6	1.7	1.7	1.7	1.75	1.7	1.75	1.8	1.7	-1.45
30	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-1.85
35	1.3	1.2	1.15	1.15	1.2	1.2	1.1	1.35	1.3	1.4	1.35	1.35	1.35	1.35	-1.5
40	0.35	0.35	0.4	0.4	0.4	0.4	0.4	0.3	0.35	0.35	0.3	0.35	0.45	0.45	-0.7

Appendix G Comparison of different T-shirts at the beginning of exercise of wearer trial analyzed by ANOVA in terms of subjective sensations.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Average Warm/Cool Sensation	Between Groups	2.930	7	.419	3.221	.004
	Within Groups	13.517	104	.130		
	Total	16.447	111			
Average Skin Wetness Sensation	Between Groups	1.010	7	.144	.876	.528
	Within Groups	17.126	104	.165		
	Total	18.136	111			
Average Comfort Sensation l	Between Groups	26.497	7	3.785	5.922	.000
	Within Groups	66.472	104	.639		
	Total	92.968	111			

Appendix H Comparison of different T-shirts in the middle of exercise of wearer trial analyzed by ANOVA in terms of subjective sensations.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Average Warm/Cool Sensation	Between Groups	2.886	7	.412	.946	.473
	Within Groups	69.761	160	.436		
	Total	72.647	167			
Average Skin Wetness Sensation	Between Groups	2.373	7	.339	.890	.516
	Within Groups	60.951	160	.381		
	Total	63.324	167			
Average Comfort Sensation	Between Groups	18.363	7	2.623	2.522	.017
	Within Groups	166.415	160	1.040		
	Total	184.778	167			

Appendix I Comparison of different T-shirts at the end of exercise of wearer trial analyzed by ANOVA in terms of subjective sensations.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Average Warm/Cool Sensation	Between Groups	2.041	7	.292	.330	.936
	Within Groups	42.387	48	.883		
	Total	44.428	55			
Average Skin Wetness Sensation	Between Groups	3.122	7	.446	.683	.686
	Within Groups	31.339	48	.653		
	Total	34.460	55			
Average Comfort Sensation	Between Groups	4.880	7	.697	.376	.912
	Within Groups	89.059	48	1.855		
	Total	93.939	55			

Appendix J Comparison of different T-shirts after exercise of wearer trial analyzed by ANOVA in terms of subjective sensations.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Average Warm/Cool Sensation	Between Groups	2.258	7	.323	1.147	.340
	Within Groups	29.242	104	.281		
	Total	31.500	111			
Average Skin Wetness Sensation	Between Groups	4.347	7	.621	2.358	.028
	Within Groups	27.388	104	.263		
	Total	31.735	111			
Average Comfort Sensation	Between Groups	8.788	7	1.255	1.240	.288
	Within Groups	105.303	104	1.013		
	Total	114.090	111			

Appendix K

Correlations between thermal comfort sensations

K-1) Regression (at the beginning of the exercise)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	Warm/Cool Sensation at 0 - 5 mins	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 0 -5 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.839(a)	.704	.679	.3217020

a Predictors: (Constant), Warm/Cool Sensation at 0 - 5 mins
b Dependent Variable: Comfort Sensation at 0 -5 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.950	1	2.950	28.500	.000(a)
	Residual	1.242	12	.103		
	Total	4.191	13			

a Predictors: (Constant), Warm/Cool Sensation at 0 - 5 mins
b Dependent Variable: Comfort Sensation at 0 -5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.621	.113		5.471	.000
	Warm/Cool Sensation at 0 - 5 mins	-2.142	.401	-.839	-5.339	.000

a Dependent Variable: Comfort Sensation at 0 -5 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Skin Wettness Sensation at 0 - 5 mins	-.117(a)	-.427	.678	-.128	.354

a Predictors in the Model: (Constant), Warm/Cool Sensation at 0 - 5 mins
b Dependent Variable: Comfort Sensation at 0 -5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.312593	1.704969	1.015475	.4763288	14
Std. Predicted Value	-1.476	1.448	.000	1.000	14
Standard Error of Predicted Value	.086	.157	.119	.027	14
Adjusted Predicted Value	.104642	1.743116	1.003065	.4897883	14
Residual	-.4130274	.6624068	.0000000	.3090813	14
Std. Residual	-1.284	2.059	.000	.961	14
Stud. Residual	-1.438	2.360	.018	1.065	14
Deleted Residual	-.5181161	.8703576	.0124103	.3806114	14
Stud. Deleted Residual	-1.513	3.087	.070	1.212	14
Mahal. Distance	.010	2.177	.929	.815	14
Cook's Distance	.000	.874	.124	.236	14
Centered Leverage Value	.001	.167	.071	.063	14

a Dependent Variable: Comfort Sensation at 0 -5 mins

K-2) Regression (in the middle of the exercise)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	Warm/Cool Sensation at 10 - 20 mins	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.813(a)	.661	.633	.2895068

a Predictors: (Constant), Warm/Cool Sensation at 10 - 20 mins
b Dependent Variable: Comfort Sensation at 10 - 20 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.962	1	1.962	23.415	.000(a)
	Residual	1.006	12	.084		
	Total	2.968	13			

a Predictors: (Constant), Warm/Cool Sensation at 10 - 20 mins
b Dependent Variable: Comfort Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.761	.286		6.149	.000
	Warm/Cool Sensation at 10 - 20 mins	-1.858	.384	-.813	-4.839	.000

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Skin Wettness Sensation at 10 - 20 mins	.091(a)	.274	.789	.082	.277

a Predictors in the Model: (Constant), Warm/Cool Sensation at 10 - 20 mins
b Dependent Variable: Comfort Sensation at 10 - 20 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.127876	1.087624	.426786	.3885361	14
Std. Predicted Value	-1.428	1.701	.000	1.000	14
Standard Error of Predicted Value	.078	.157	.107	.025	14
Adjusted Predicted Value	-.233441	1.137985	.424475	.3989802	14
Residual	-.4134477	.4622541	.0000000	.2781491	14
Std. Residual	-1.428	1.597	.000	.961	14
Stud. Residual	-1.483	1.691	.004	1.031	14
Deleted Residual	-.4461085	.5182707	.0023108	.3212731	14
Stud. Deleted Residual	-1.572	1.855	.020	1.069	14
Mahal. Distance	.004	2.893	.929	.870	14
Cook's Distance	.004	.291	.078	.075	14
Centered Leverage Value	.000	.223	.071	.067	14

a Dependent Variable: Comfort Sensation at 10 - 20 mins

K-3) Regression (at the end of the exercise)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	Warm/Cool Sensation at 30 mins	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 30 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.701(a)	.491	.449	.3549728

a Predictors: (Constant), Warm/Cool Sensation at 30 mins
b Dependent Variable: Comfort Sensation at 30 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.459	1	1.459	11.582	.005(a)
	Residual	1.512	12	.126		
	Total	2.971	13			

a Predictors: (Constant), Warm/Cool Sensation at 30 mins
b Dependent Variable: Comfort Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.661	.474		3.506	.004
	Warm/Cool Sensation at 30 mins	-1.222	.359	-.701	-3.403	.005

a Dependent Variable: Comfort Sensation at 30 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Skin Wettness Sensation at 30 mins	-.334(a)	-.352	.731	-.106	.051

a Predictors in the Model: (Constant), Warm/Cool Sensation at 30 mins
b Dependent Variable: Comfort Sensation at 30 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.599438	.652853	.081250	.3350564	14
Std. Predicted Value	-2.032	1.706	.000	1.000	14
Standard Error of Predicted Value	.095	.221	.128	.041	14
Adjusted Predicted Value	-.861603	.612144	.062271	.3652936	14
Residual	-.6905669	.4330205	.0000000	.3410468	14
Std. Residual	-1.945	1.220	.000	.961	14
Stud. Residual	-2.019	1.485	.023	1.036	14
Deleted Residual	-.7439488	.6741029	.0189789	.4008995	14
Stud. Deleted Residual	-2.379	1.573	-.001	1.110	14
Mahal. Distance	.004	4.127	.929	1.287	14
Cook's Distance	.001	.701	.095	.180	14
Centered Leverage Value	.000	.317	.071	.099	14

a Dependent Variable: Comfort Sensation at 30 mins

K-4) Regression (after exercise)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	Skin Wettness Sensation at 35 - 40 mins	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.565(a)	.319	.262	.4462994

a Predictors: (Constant), Skin Wettness Sensation at 35 - 40 mins
b Dependent Variable: Comfort Sensation at 35 - 40 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.119	1	1.119	5.617	.035(a)
	Residual	2.390	12	.199		
	Total	3.509	13			

a Predictors: (Constant), Skin Wettness Sensation at 35 - 40 mins
b Dependent Variable: Comfort Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.915	.158		5.787	.000
	Skin Wettness Sensation at 35 - 40 mins	-1.097	.463	-.565	-2.370	.035

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Warm/Cool Sensation at 35 - 40 mins	.067(a)	.117	.909	.035	.186

a Predictors in the Model: (Constant), Skin Wettness Sensation at 35 - 40 mins
b Dependent Variable: Comfort Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.339678	1.313055	.669196	.2933655	14
Std. Predicted Value	-1.123	2.195	.000	1.000	14
Standard Error of Predicted Value	.119	.297	.161	.053	14
Adjusted Predicted Value	.312410	1.250763	.665430	.2858129	14
Residual	-.6775782	.6210099	.0000000	.4287906	14
Std. Residual	-1.518	1.391	.000	.961	14
Stud. Residual	-1.577	1.451	.003	1.020	14
Deleted Residual	-.7309182	.6748232	.0037661	.4843598	14
Stud. Deleted Residual	-1.696	1.529	-.008	1.056	14
Mahal. Distance	.000	4.817	.929	1.400	14
Cook's Distance	.007	.199	.064	.059	14
Centered Leverage Value	.000	.371	.071	.108	14

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Appendix L

Factor Analysis between fabric/clothing properties

Communalities

	Initial	Extraction
mass per unit area (g/m2)	1.000	.939
thickness (mm)	1.000	.967
Air Permeability (cm3/s/cm2)	1.000	.721
thermal insulation (clo)	1.000	.965
q-max (W/cm2)	1.000	.878
Water Vapor Transmission Rate (g/hr.m2)	1.000	.918
Wicking level (cm) at 5 mins	1.000	.683
Moisture Regain (%)	1.000	.967
Thermal insulation by Walter (m2oC/w)	1.000	.905
Water Vapour Resistance by Walter (m2Pa/w)	1.000	.920

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotatio
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.812	38.123	38.123	3.812	38.123	38.123	2.690
2	2.824	28.237	66.360	2.824	28.237	66.360	2.627
3	1.278	12.777	79.137	1.278	12.777	79.137	2.243
4	.949	9.488	88.626	.949	9.488	88.626	1.302
5	.579	5.791	94.417				
6	.257	2.569	96.986				
7	.147	1.472	98.458				
8	.113	1.127	99.585				
9	.035	.350	99.935				
10	.006	.065	100.000				

Extraction Method: Principal Component Analysis.

Component Matrix(a)

	Component			
	1	2	3	4
mass per unit area (g/m2)	.813	.069	.256	.456
thickness (mm)	.470	.815	.254	-.132
Air Permeability (cm3/s/cm2)	-.757	.275	-.267	.015
thermal insulation (clo)	-.041	.973	.104	-.077
q-max (W/cm2)	.478	-.796	.006	.125
Water Vapor Transmission Rate (g/hr.m2)	-.792	-.174	.405	-.312
Wicking level (cm) at 5 mins	-.727	.348	.053	.175
Moisture Regain (%)	.610	-.087	.543	-.541
Thermal insulation by Walter (m2oC/w)	-.379	.081	.692	.526
Water Vapour Resistance by Walter (m2Pa/w)	.675	.578	-.354	.072

Extraction Method: Principal Component Analysis.
a 4 components extracted.

Rotated Component Matrix(a)

	Component			
	1	2	3	4
mass per unit area (g/m2)	-.009	.825	.425	.278
thickness (mm)	.846	.364	.343	.017
Air Permeability (cm3/s/cm2)	.230	-.438	-.690	-.004
thermal insulation (clo)	.969	.081	-.121	.064
q-max (W/cm2)	-.799	.278	.399	-.052
Water Vapor Transmission Rate (g/hr.m2)	-.025	-.907	-.070	.300
Wicking level (cm) at 5 mins	.312	-.387	-.573	.329
Moisture Regain (%)	.115	-.014	.974	-.070
Thermal insulation by Walter (m2oC/w)	.068	-.128	-.094	.936
Water Vapour Resistance by Walter (m2Pa/w)	.477	.742	.062	-.372

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 6 iterations.

Component Transformation Matrix

Component	1	2	3	4
1	-.012	.746	.621	-.240
2	.962	.188	-.198	.023
3	.152	-.246	.590	.754
4	-.228	.590	-.476	.611

Extraction Method: Principal Component Analysis.   Rotation Method: Varimax with Kaiser Normalization.

Appendix M

Correlations between four factors and comfort sensations during different stages

A) At the beginning of exercise

M-1) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.717(a)	.514	.474	.1613216

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.330	1	.330	12.699	.004(a)
	Residual	.312	12	.026		
	Total	.643	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.184	.043		-4.276	.001
	REGR factor score 1 for analysis 6	.159	.045	.717	3.564	.004

a Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.284(a)	1.482	.166	.408	1.000
	REGR factor score 3 for analysis 6	.135(a)	.656	.525	.194	1.000
	REGR factor score 4 for analysis 6	.291(a)	1.527	.155	.418	1.000

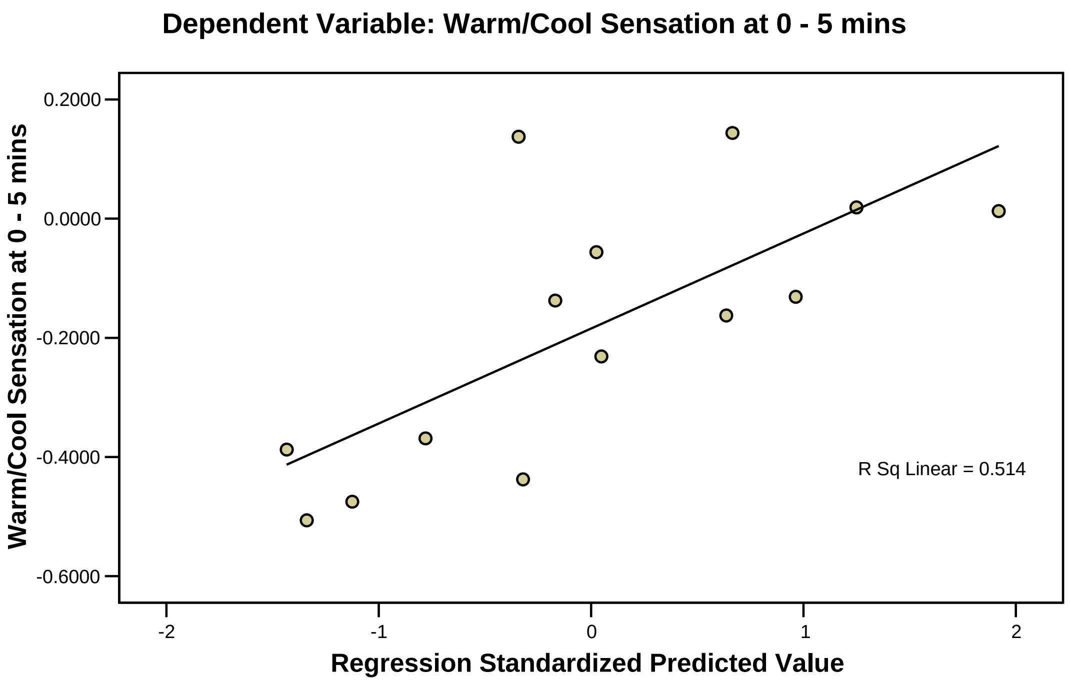
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.412989	.121728	-.184375	.1594455	14
Residual	-.2019739	.3763339	.0000000	.1549928	14
Std. Predicted Value	-1.434	1.920	.000	1.000	14
Std. Residual	-1.252	2.333	.000	.961	14

a Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Scatterplot



M-2) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.681(a)	.464	.419	.0988739

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.101	1	.101	10.375	.007(a)
	Residual	.117	12	.010		
	Total	.219	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.463	.026		-17.536	.000
	REGR factor score 1 for analysis 6	.088	.027	.681	3.221	.007

a Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.152(a)	.705	.495	.208	1.000
	REGR factor score 3 for analysis 6	.121(a)	.556	.589	.165	1.000
	REGR factor score 4 for analysis 6	.198(a)	.932	.371	.271	1.000

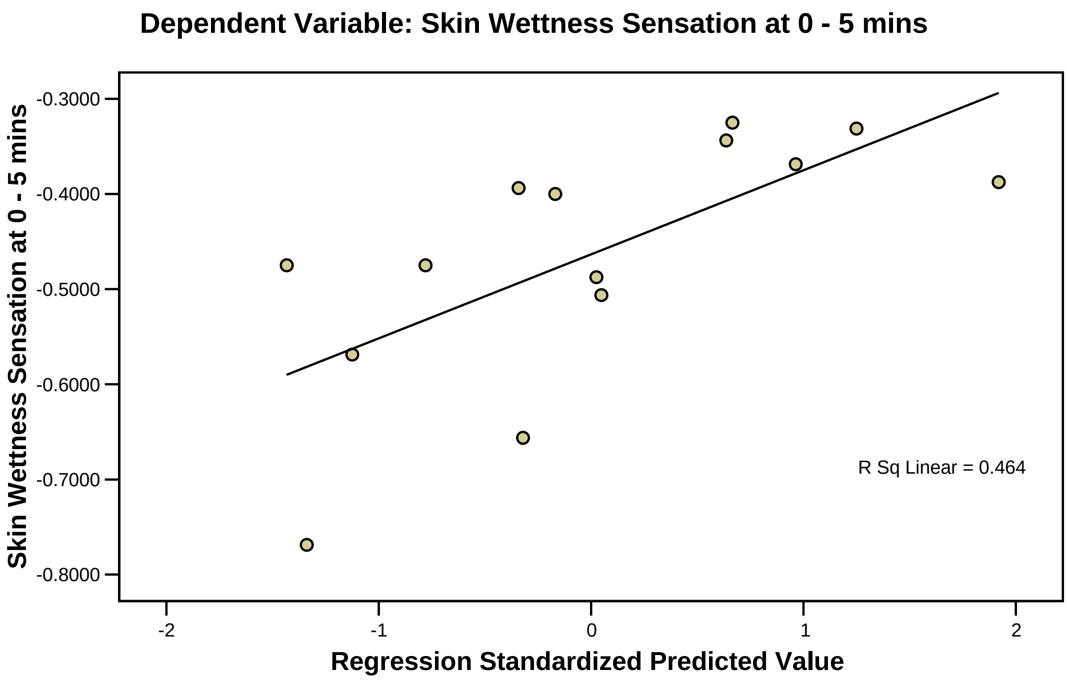
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.590039	-.293819	-.463393	.0883290	14
Residual	-.1870629	.1150394	.0000000	.0949950	14
Std. Predicted Value	-1.434	1.920	.000	1.000	14
Std. Residual	-1.892	1.163	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Scatterplot



M-3) Regression (overall comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	REGR factor score 4 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 0 -5 mins

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.696(a)	.484	.441	.4245406
2	.820(b)	.673	.613	.3531292

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 4 for analysis 6
c Dependent Variable: Comfort Sensation at 0 -5 mins

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.029	1	2.029	11.256	.006(a)
	Residual	2.163	12	.180		
	Total	4.191	13			
2	Regression	2.820	2	1.410	11.306	.002(b)
	Residual	1.372	11	.125		
	Total	4.191	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 4 for analysis 6
c Dependent Variable: Comfort Sensation at 0 -5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.015	.113		8.950	.000
	REGR factor score 1 for analysis 6	-.395	.118	-.696	-3.355	.006
2	(Constant)	1.015	.094		10.760	.000
	REGR factor score 1 for analysis 6	-.395	.098	-.696	-4.033	.002
	REGR factor score 4 for analysis 6	-.247	.098	-.434	-2.519	.029

a Dependent Variable: Comfort Sensation at 0 -5 mins

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	-.095(a)	-.443	.666	-.132	1.000
	REGR factor score 3 for analysis 6	-.308(a)	-1.572	.144	-.428	1.000
	REGR factor score 4 for analysis 6	-.434(a)	-2.519	.029	-.605	1.000
2	REGR factor score 2 for analysis 6	-.095(b)	-.533	.605	-.166	1.000
	REGR factor score 3 for analysis 6	-.308(b)	-2.018	.071	-.538	1.000

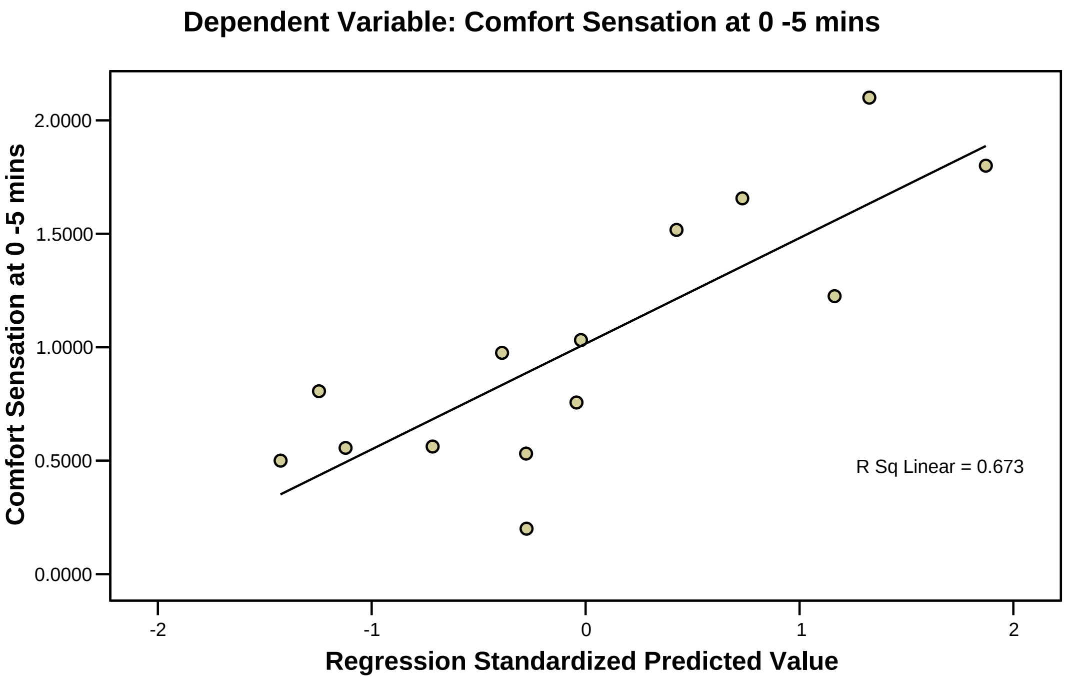
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 4 for analysis 6
c Dependent Variable: Comfort Sensation at 0 -5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.351235	1.886835	1.015475	.4657304	14
Residual	-.6869067	.4668137	.0000000	.3248317	14
Std. Predicted Value	-1.426	1.871	.000	1.000	14
Std. Residual	-1.945	1.322	.000	.920	14

a Dependent Variable: Comfort Sensation at 0 -5 mins

Scatterplot



(B) In the middle of the exercise

M-4) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 5	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).
2	REGR factor score 2 for analysis 5	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).

a Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.793(a)	.628	.598	.1326570
2	.856(b)	.733	.685	.1174389

a Predictors: (Constant), REGR factor score 1 for analysis 5
b Predictors: (Constant), REGR factor score 1 for analysis 5, REGR factor score 2 for analysis 5
c Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.357	1	.357	20.301	.001(a)
	Residual	.211	12	.018		
	Total	.568	13			
2	Regression	.417	2	.208	15.107	.001(b)
	Residual	.152	11	.014		
	Total	.568	13			

a Predictors: (Constant), REGR factor score 1 for analysis 5
b Predictors: (Constant), REGR factor score 1 for analysis 5, REGR factor score 2 for analysis 5
c Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.718	.035		20.256	.000
	REGR factor score 1 for analysis 5	.166	.037	.793	4.506	.001
2	(Constant)	.718	.031		22.881	.000
	REGR factor score 1 for analysis 5	.166	.033	.793	5.089	.000
	REGR factor score 2 for analysis 5	.068	.033	.323	2.076	.062

a Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 5	.323(a)	2.076	.062	.531	1.000
	REGR factor score 3 for analysis 5	.030(a)	.165	.872	.050	1.000
	REGR factor score 4 for analysis 5	.073(a)	.400	.697	.120	1.000
2	REGR factor score 3 for analysis 5	.030(b)	.185	.857	.059	1.000
	REGR factor score 4 for analysis 5	.073(b)	.451	.661	.141	1.000

a Predictors in the Model: (Constant), REGR factor score 1 for analysis 5
b Predictors in the Model: (Constant), REGR factor score 1 for analysis 5, REGR factor score 2 for analysis 5
c Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

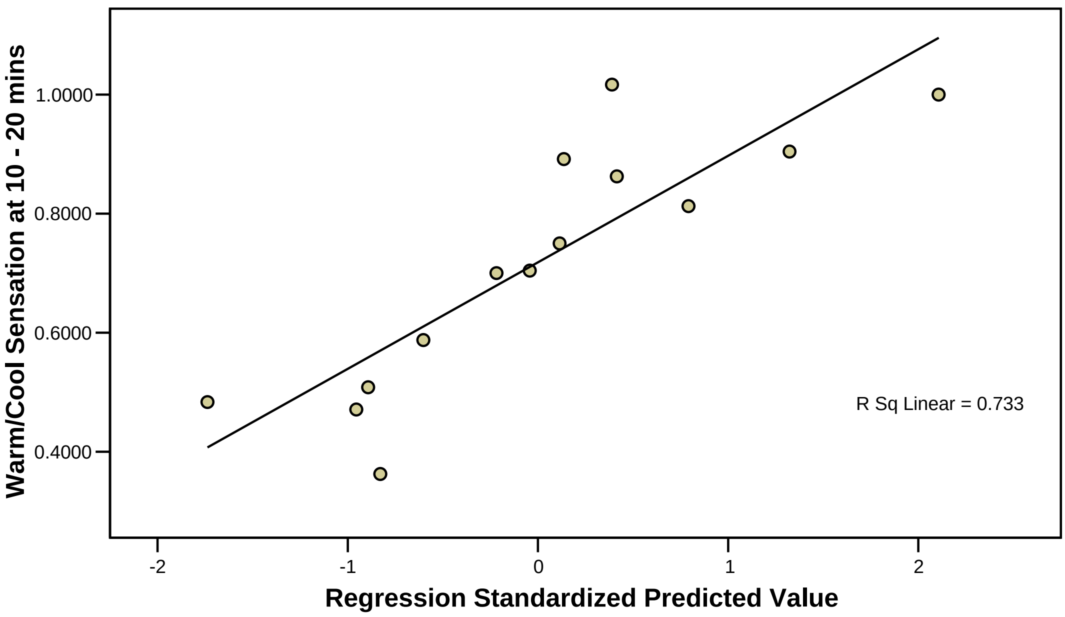
Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.407008	1.095408	.718155	.1790387	14
Residual	-.2073383	.2288282	.0000000	.1080280	14
Std. Predicted Value	-1.738	2.107	.000	1.000	14
Std. Residual	-1.765	1.948	.000	.920	14

a Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Scatterplot

Dependent Variable: Warm/Cool Sensation at 10 - 20 mins



M-5) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.804(a)	.647	.617	.1272317

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.356	1	.356	21.985	.001(a)
	Residual	.194	12	.016		
	Total	.550	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.274	.034		8.061	.000
	REGR factor score 1 for analysis 6	.165	.035	.804	4.689	.001

a Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.120(a)	.685	.508	.202	1.000
	REGR factor score 3 for analysis 6	-.073(a)	-.413	.688	-.124	1.000
	REGR factor score 4 for analysis 6	-.166(a)	-.963	.356	-.279	1.000

a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

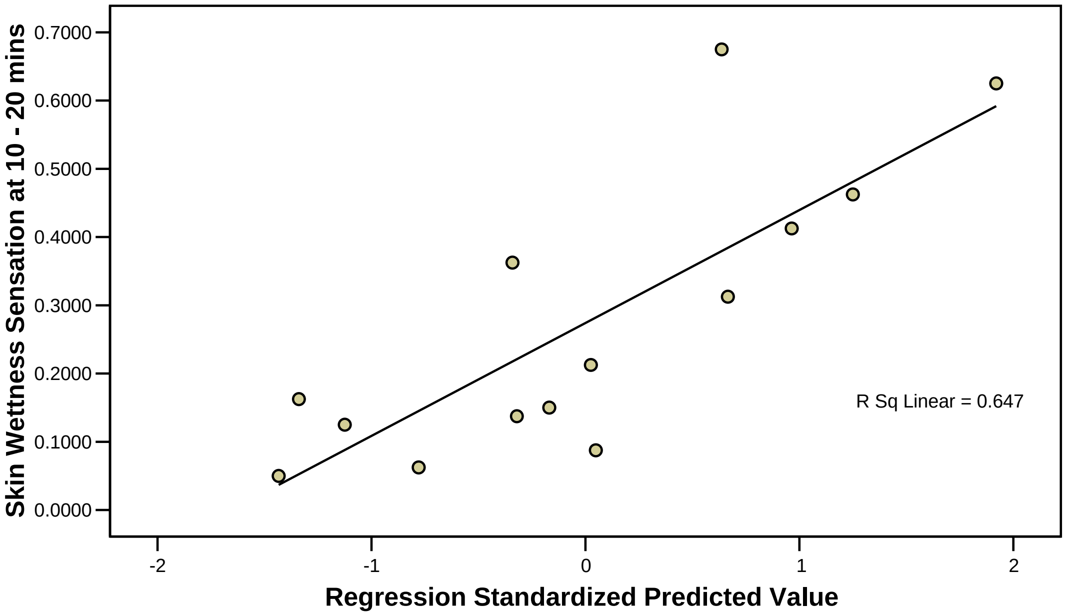
Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.036873	.591752	.274107	.1654574	14
Residual	-.1945789	.2955626	.0000000	.1222403	14
Std. Predicted Value	-1.434	1.920	.000	1.000	14
Std. Residual	-1.529	2.323	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Scatterplot

Dependent Variable: Skin Wettness Sensation at 10 - 20 mins



M-6) Regression (overall comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.716(a)	.512	.472	.3472786

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Comfort Sensation at 10 - 20 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.521	1	1.521	12.612	.004(a)
	Residual	1.447	12	.121		
	Total	2.968	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Comfort Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.427	.093		4.598	.001
	REGR factor score 1 for analysis 6	-.342	.096	-.716	-3.551	.004

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	-.223(a)	-1.118	.287	-.319	1.000
	REGR factor score 3 for analysis 6	-.206(a)	-1.025	.327	-.295	1.000
	REGR factor score 4 for analysis 6	-.306(a)	-1.619	.134	-.439	1.000

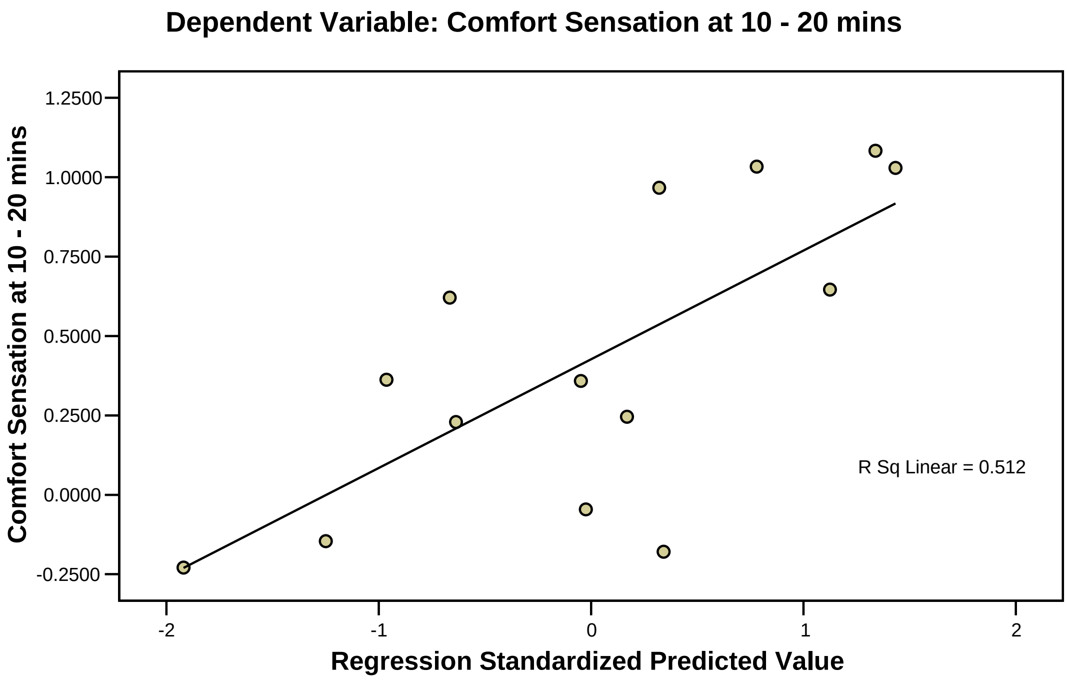
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Comfort Sensation at 10 - 20 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.229892	.917226	.426786	.3420554	14
Residual	-.7227821	.4301475	.0000000	.3336545	14
Std. Predicted Value	-1.920	1.434	.000	1.000	14
Std. Residual	-2.081	1.239	.000	.961	14

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Scatterplot



(C) At the end of the exercise

M-7 Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Warm/Cool Sensation at 30 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.610(a)	.372	.319	.2262849

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Warm/Cool Sensation at 30 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.363	1	.363	7.094	.021(a)
	Residual	.614	12	.051		
	Total	.978	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Warm/Cool Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.293	.060		21.378	.000
	REGR factor score 1 for analysis 6	.167	.063	.610	2.664	.021

a Dependent Variable: Warm/Cool Sensation at 30 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.134(a)	.571	.580	.170	1.000
	REGR factor score 3 for analysis 6	.124(a)	.523	.611	.156	1.000
	REGR factor score 4 for analysis 6	-.128(a)	-.543	.598	-.162	1.000

a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Warm/Cool Sensation at 30 mins

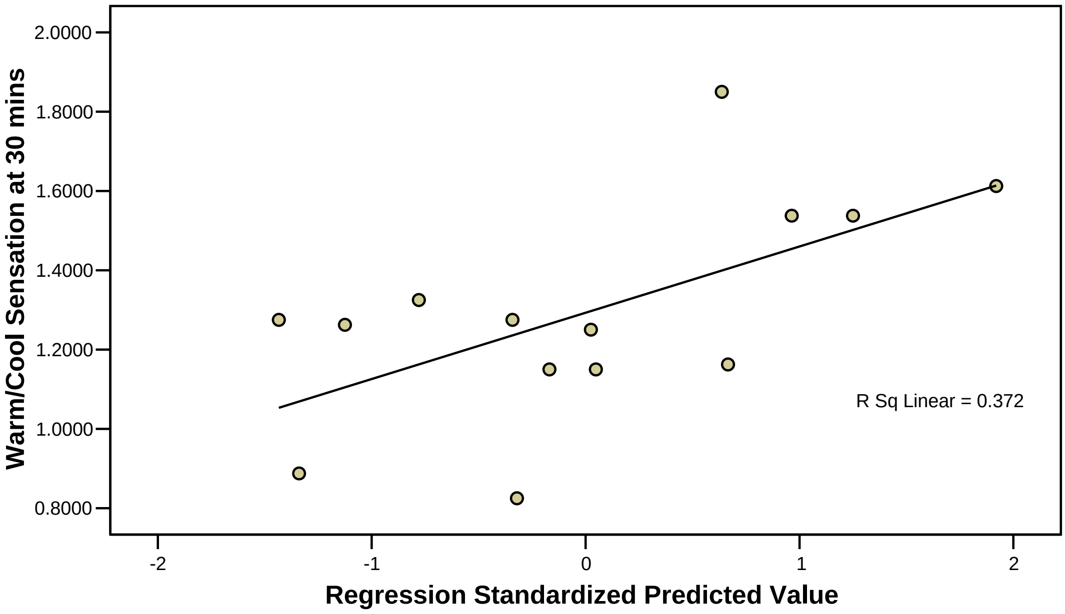
Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.053178	1.613777	1.292857	.1671629	14
Residual	-.4142302	.4507268	.0000000	.2174075	14
Std. Predicted Value	-1.434	1.920	.000	1.000	14
Std. Residual	-1.831	1.992	.000	.961	14

a Dependent Variable: Warm/Cool Sensation at 30 mins

Scatterplot

Dependent Variable: Warm/Cool Sensation at 30 mins



M-8) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Skin Wettness Sensation at 30 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.645(a)	.415	.367	.2722326

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 30 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.632	1	.632	8.530	.013(a)
	Residual	.889	12	.074		
	Total	1.521	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.344	.073		18.469	.000
	REGR factor score 1 for analysis 6	.221	.076	.645	2.921	.013

a Dependent Variable: Skin Wettness Sensation at 30 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.131(a)	.579	.574	.172	1.000
	REGR factor score 3 for analysis 6	.180(a)	.805	.438	.236	1.000
	REGR factor score 4 for analysis 6	.012(a)	.052	.959	.016	1.000

a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Dependent Variable: Skin Wettness Sensation at 30 mins

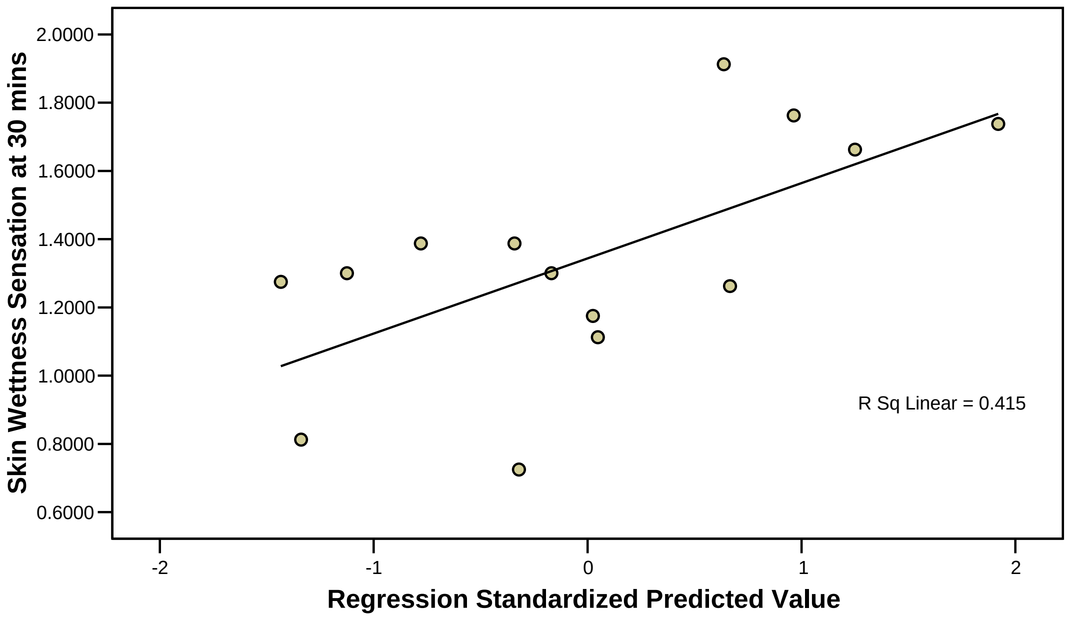
Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.027573	1.767097	1.343750	.2205164	14
Residual	-.5480070	.4283692	.0000000	.2615527	14
Std. Predicted Value	-1.434	1.920	.000	1.000	14
Std. Residual	-2.013	1.574	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 30 mins

Scatterplot

Dependent Variable: Skin Wettness Sensation at 30 mins



M-9) Regression (overall comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	REGR factor score 2 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 30 mins

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.629(a)	.395	.345	.3868976
2	.786(b)	.618	.548	.3212747

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Dependent Variable: Comfort Sensation at 30 mins

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.175	1	1.175	7.851	.016(a)
	Residual	1.796	12	.150		
	Total	2.971	13			
2	Regression	1.836	2	.918	8.894	.005(b)
	Residual	1.135	11	.103		
	Total	2.971	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Dependent Variable: Comfort Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.081	.103		.786	.447
	REGR factor score 1 for analysis 6	-.301	.107	-.629	-2.802	.016
2	(Constant)	.081	.086		.946	.364
	REGR factor score 1 for analysis 6	-.301	.089	-.629	-3.374	.006
	REGR factor score 2 for analysis 6	-.225	.089	-.472	-2.530	.028

a Dependent Variable: Comfort Sensation at 30 mins

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	-.472(a)	-2.530	.028	-.607	1.000
	REGR factor score 3 for analysis 6	-.257(a)	-1.160	.271	-.330	1.000
	REGR factor score 4 for analysis 6	-.141(a)	-.610	.554	-.181	1.000
2	REGR factor score 3 for analysis 6	-.257(b)	-1.444	.179	-.415	1.000
	REGR factor score 4 for analysis 6	-.141(b)	-.739	.477	-.227	1.000

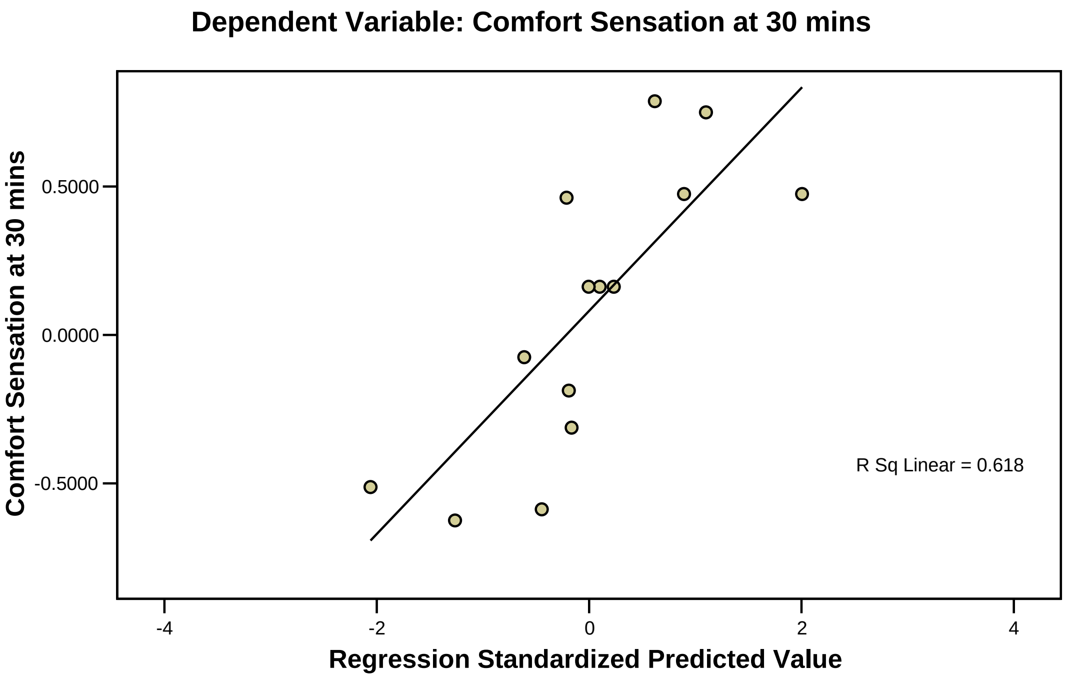
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Dependent Variable: Comfort Sensation at 30 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.692671	.835065	.081250	.3758163	14
Residual	-.5012037	.4737292	.0000000	.2955298	14
Std. Predicted Value	-2.059	2.006	.000	1.000	14
Std. Residual	-1.560	1.475	.000	.920	14

a Dependent Variable: Comfort Sensation at 30 mins

Scatterplot



(D) After exercise

M-10) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .400, Probability-of-F-to-remove >= .500).
2	REGR factor score 2 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .400, Probability-of-F-to-remove >= .500).
3	REGR factor score 4 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .400, Probability-of-F-to-remove >= .500).

a Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Model Summary(d)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.362(a)	.131	.059	.1921687
2	.492(b)	.242	.105	.1874201
3	.548(c)	.301	.091	.1888714

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6 , REGR factor score 4 for analysis 6
d Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

ANOVA(d)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.067	1	.067	1.811	.203(a)
	Residual	.443	12	.037		
	Total	.510	13			
2	Regression	.124	2	.062	1.760	.217(b)
	Residual	.386	11	.035		
	Total	.510	13			
3	Regression	.153	3	.051	1.433	.291(c)
	Residual	.357	10	.036		
	Total	.510	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6 , REGR factor score 4 for analysis 6
d Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.232	.051		4.511	.001
	REGR factor score 1 for analysis 6	.072	.053	.362	1.346	.203
2	(Constant)	.232	.050		4.626	.001
	REGR factor score 1 for analysis 6	.072	.052	.362	1.380	.195
	REGR factor score 2 for analysis 6	.066	.052	.334	1.271	.230
3	(Constant)	.232	.050		4.590	.001
	REGR factor score 1 for analysis 6	.072	.052	.362	1.369	.201
	REGR factor score 2 for analysis 6	.066	.052	.334	1.261	.236
	REGR factor score 4 for analysis 6	.048	.052	.241	.912	.383

a Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Excluded Variables(d)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.334(a)	1.271	.230	.358	1.000
	REGR factor score 3 for analysis 6	.212(a)	.775	.455	.227	1.000
	REGR factor score 4 for analysis 6	.241(a)	.888	.393	.259	1.000
2	REGR factor score 3 for analysis 6	.212(b)	.794	.446	.244	1.000
	REGR factor score 4 for analysis 6	.241(b)	.912	.383	.277	1.000
3	REGR factor score 3 for analysis 6	.212(c)	.786	.452	.253	1.000

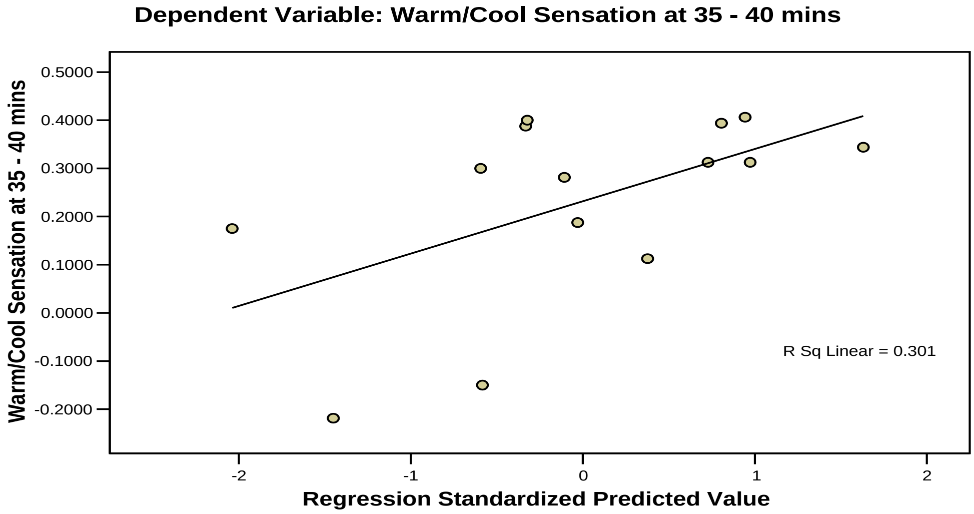
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6 , REGR factor score 4 for analysis 6
d Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.010293	.408821	.231696	.1085967	14
Residual	-.3183217	.2033536	.0000000	.1656512	14
Std. Predicted Value	-2.039	1.631	.000	1.000	14
Std. Residual	-1.685	1.077	.000	.877	14

a Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Scatterplot



M-11) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .400, Probability-of-F-to-remove >= .500).
2	REGR factor score 3 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .400, Probability-of-F-to-remove >= .500).
3	REGR factor score 2 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .400, Probability-of-F-to-remove >= .500).

a Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Model Summary(d)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.427(a)	.182	.114	.2517323
2	.515(b)	.266	.132	.2491955
3	.581(c)	.337	.139	.2482665

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 3 for analysis 6
c Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 3 for analysis 6 , REGR factor score 2 for analysis 6
d Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

ANOVA(d)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.170	1	.170	2.678	.128(a)
	Residual	.760	12	.063		
	Total	.930	13			
2	Regression	.247	2	.124	1.989	.183(b)
	Residual	.683	11	.062		
	Total	.930	13			
3	Regression	.314	3	.105	1.697	.230(c)
	Residual	.616	10	.062		
	Total	.930	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 3 for analysis 6
c Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 3 for analysis 6 , REGR factor score 2 for analysis 6
d Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.225	.067		3.338	.006
	REGR factor score 1 for analysis 6	.114	.070	.427	1.636	.128
2	(Constant)	.225	.067		3.372	.006
	REGR factor score 1 for analysis 6	.114	.069	.427	1.653	.127
	REGR factor score 3 for analysis 6	.077	.069	.288	1.116	.288
3	(Constant)	.225	.066		3.384	.007
	REGR factor score 1 for analysis 6	.114	.069	.427	1.659	.128
	REGR factor score 3 for analysis 6	.077	.069	.288	1.120	.289
	REGR factor score 2 for analysis 6	.072	.069	.268	1.040	.323

a Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Excluded Variables(d)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	.268(a)	1.029	.326	.296	1.000
	REGR factor score 3 for analysis 6	.288(a)	1.116	.288	.319	1.000
	REGR factor score 4 for analysis 6	.163(a)	.609	.555	.181	1.000
2	REGR factor score 2 for analysis 6	.268(b)	1.040	.323	.313	1.000
	REGR factor score 4 for analysis 6	.163(b)	.614	.553	.191	1.000
3	REGR factor score 4 for analysis 6	.163(c)	.614	.554	.201	1.000

a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 3 for analysis 6
c Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 3 for analysis 6 , REGR factor score 2 for analysis 6
d Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.018535	.517413	.224554	.1553536	14
Residual	-.3549919	.3514626	.0000000	.2177442	14
Std. Predicted Value	-1.565	1.885	.000	1.000	14
Std. Residual	-1.430	1.416	.000	.877	14

a Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

M-12) Regression (overall comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	REGR factor score 1 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).
2	REGR factor score 2 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).
3	REGR factor score 3 for analysis 6	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Model Summary(d)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.517(a)	.267	.206	.4628607
2	.706(b)	.499	.407	.3999637
3	.838(c)	.702	.612	.3234884

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6 , REGR factor score 3 for analysis 6
d Dependent Variable: Comfort Sensation at 35 - 40 mins

ANOVA(d)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.938	1	.938	4.379	.058(a)
	Residual	2.571	12	.214		
	Total	3.509	13			
2	Regression	1.749	2	.875	5.468	.022(b)
	Residual	1.760	11	.160		
	Total	3.509	13			
3	Regression	2.463	3	.821	7.844	.006(c)
	Residual	1.046	10	.105		
	Total	3.509	13			

a Predictors: (Constant), REGR factor score 1 for analysis 6
b Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Predictors: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6 , REGR factor score 3 for analysis 6
d Dependent Variable: Comfort Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.669	.124		5.410	.000
	REGR factor score 1 for analysis 6	-.269	.128	-.517	-2.093	.058
2	(Constant)	.669	.107		6.260	.000
	REGR factor score 1 for analysis 6	-.269	.111	-.517	-2.422	.034
	REGR factor score 2 for analysis 6	-.250	.111	-.481	-2.252	.046
3	(Constant)	.669	.086		7.740	.000
	REGR factor score 1 for analysis 6	-.269	.090	-.517	-2.994	.013
	REGR factor score 2 for analysis 6	-.250	.090	-.481	-2.784	.019
	REGR factor score 3 for analysis 6	-.234	.090	-.451	-2.611	.026

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Excluded Variables(d)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	REGR factor score 2 for analysis 6	-.481(a)	-2.252	.046	-.562	1.000
	REGR factor score 3 for analysis 6	-.451(a)	-2.055	.064	-.527	1.000
	REGR factor score 4 for analysis 6	.047(a)	.183	.858	.055	1.000
2	REGR factor score 3 for analysis 6	-.451(b)	-2.611	.026	-.637	1.000
	REGR factor score 4 for analysis 6	.047(b)	.211	.837	.067	1.000
3	REGR factor score 4 for analysis 6	.047(c)	.260	.801	.086	1.000

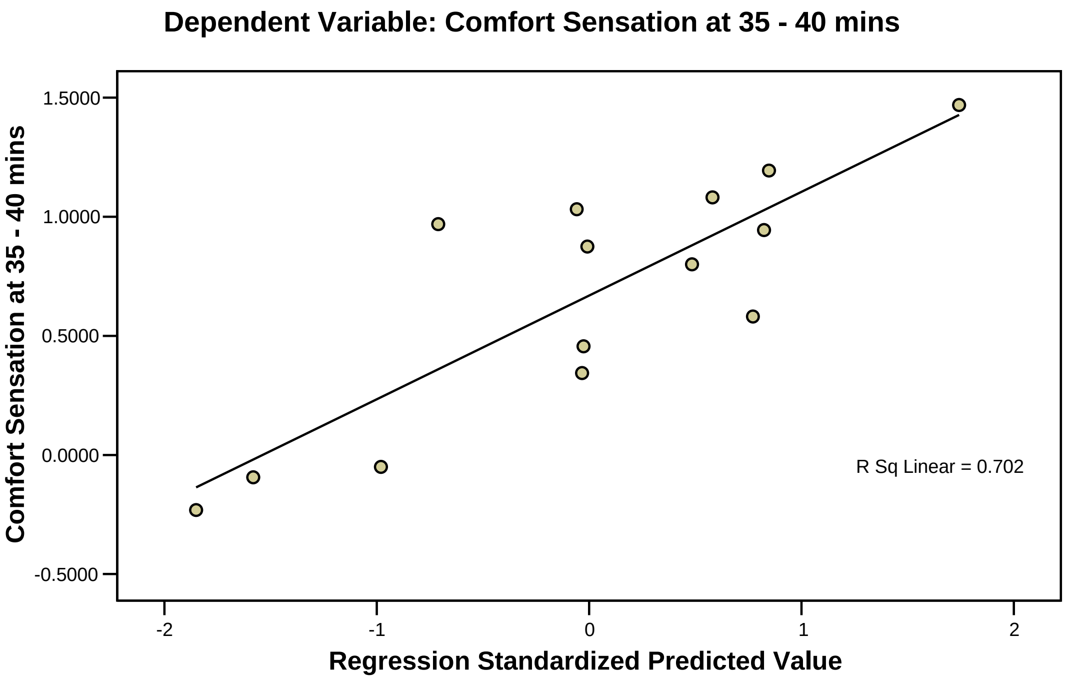
a Predictors in the Model: (Constant), REGR factor score 1 for analysis 6
b Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6
c Predictors in the Model: (Constant), REGR factor score 1 for analysis 6 , REGR factor score 2 for analysis 6 , REGR factor score 3 for analysis 6
d Dependent Variable: Comfort Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.136388	1.427623	.669196	.4352341	14
Residual	-.4236766	.6088211	.0000000	.2837181	14
Std. Predicted Value	-1.851	1.743	.000	1.000	14
Std. Residual	-1.310	1.882	.000	.877	14

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Scatterplot



Appendix N

Correlations between thermal properties and comfort sensation by Multiple Linear Regression

(A) At the beginning of exercise

N-1) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.712(a)	.507	.466	.1624249

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.326	1	.326	12.365	.004(a)
	Residual	.317	12	.026		
	Total	.643	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.865	.198		-4.361	.001
	thickness (mm)	.917	.261	.712	3.516	.004

a Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	.031(a)	.132	.897	.040	.800
	Air Permeability (cm3/s/cm2)	.006(a)	.026	.980	.008	.982
	thermal insulation (clo)	.253(a)	.697	.500	.206	.326
	q-max (W/cm2)	-.268(a)	-1.250	.237	-.353	.855
	Water Vapor Transmission Rate (g/hr.m2)	.080(a)	.354	.730	.106	.860
	Wicking level (cm) at 5 mins	.244(a)	1.226	.246	.347	.994
	Moisture Regain (%)	-.092(a)	-.394	.701	-.118	.813
	Thermal insulation by Walter (m2oC/w)	.302(a)	1.582	.142	.430	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.106(a)	.372	.717	.111	.545

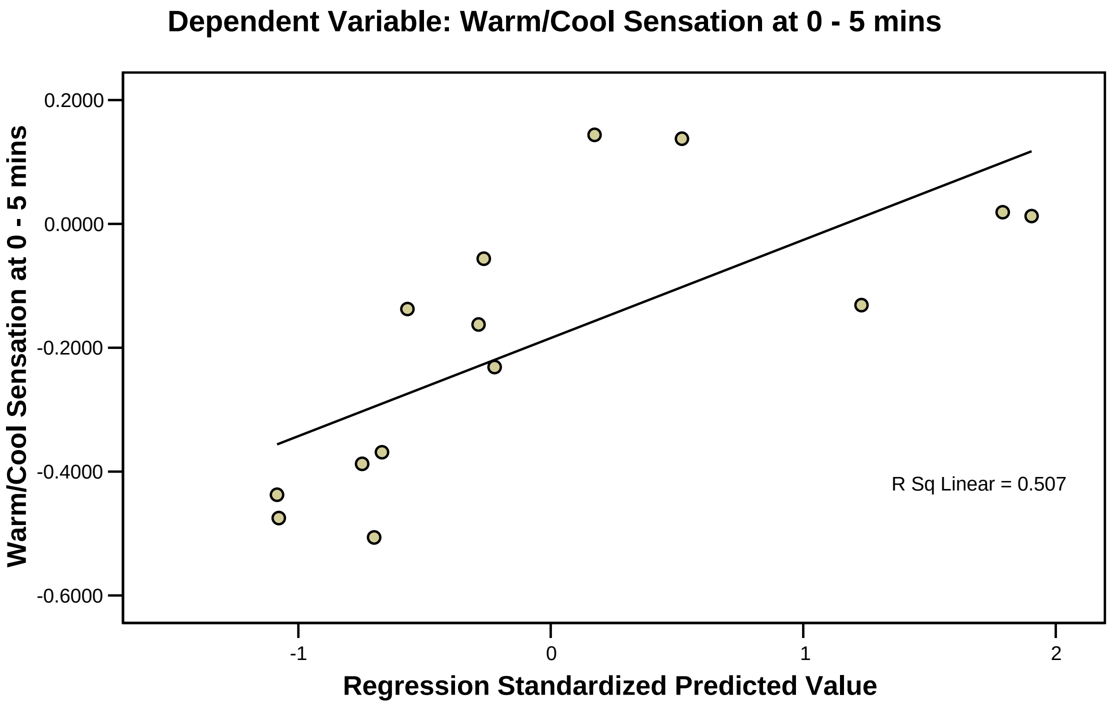
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.356103	.117325	-.184375	.1584081	14
Residual	-.2110450	.3006501	.0000000	.1560528	14
Std. Predicted Value	-1.084	1.905	.000	1.000	14
Std. Residual	-1.299	1.851	.000	.961	14

a Dependent Variable: Warm/Cool Sensation at 0 - 5 mins

Scatterplot



N-2) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.626(a)	.392	.342	.1052565

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.086	1	.086	7.744	.017(a)
	Residual	.133	12	.011		
	Total	.219	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.812	.129		-6.320	.000
	thickness (mm)	.470	.169	.626	2.783	.017

a Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.174(a)	-.676	.513	-.200	.800
	Air Permeability (cm3/s/cm2)	-.020(a)	-.086	.933	-.026	.982
	thermal insulation (clo)	.231(a)	.569	.581	.169	.326
	q-max (W/cm2)	-.340(a)	-1.460	.172	-.403	.855
	Water Vapor Transmission Rate (g/hr.m2)	.177(a)	.714	.490	.210	.860
	Wicking level (cm) at 5 mins	.247(a)	1.102	.294	.315	.994
	Moisture Regain (%)	-.086(a)	-.332	.746	-.100	.813
	Thermal insulation by Walter (m2oC/w)	.269(a)	1.221	.248	.345	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.184(a)	.587	.569	.174	.545

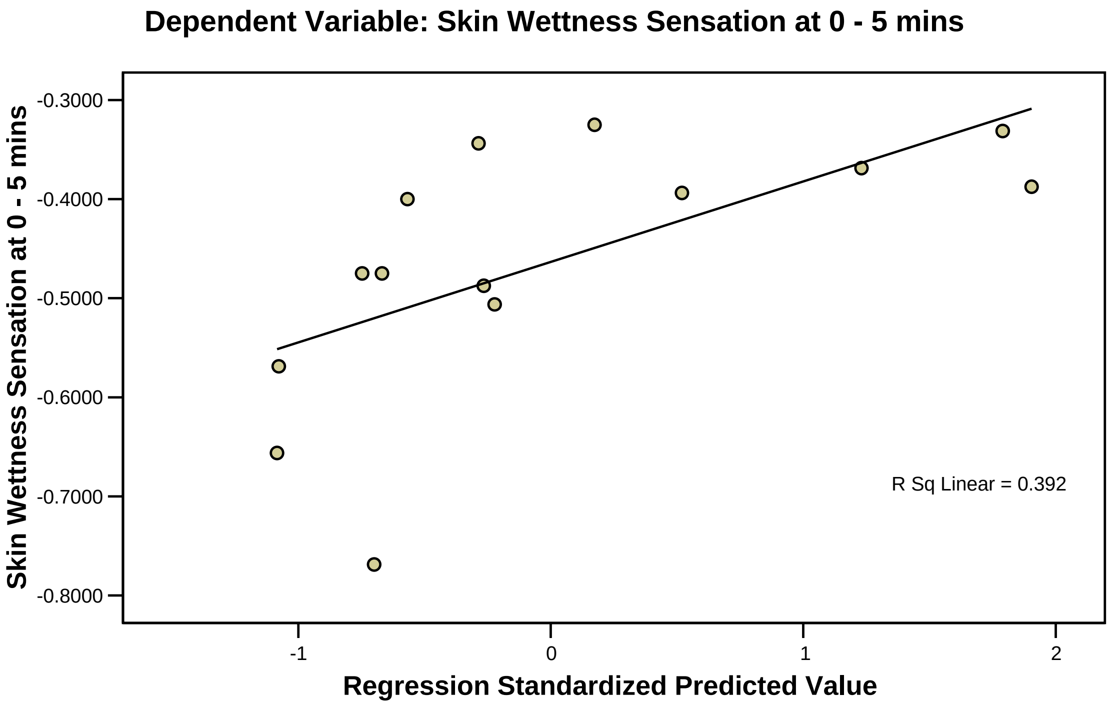
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.551460	-.308672	-.463393	.0812364	14
Residual	-.2485202	.1428977	.0000000	.1011272	14
Std. Predicted Value	-1.084	1.905	.000	1.000	14
Std. Residual	-2.361	1.358	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 0 - 5 mins

Scatterplot



N-3) Regression (Overall Comfort Sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 0 -5 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.689(a)	.475	.431	.4281628

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 0 -5 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.992	1	1.992	10.864	.006(a)
	Residual	2.200	12	.183		
	Total	4.191	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 0 -5 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.697	.523		5.158	.000
	thickness (mm)	-2.266	.688	-.689	-3.296	.006

a Dependent Variable: Comfort Sensation at 0 -5 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.049(a)	-.199	.846	-.060	.800
	Air Permeability (cm3/s/cm2)	.152(a)	.704	.496	.208	.982
	thermal insulation (clo)	-.315(a)	-.850	.414	-.248	.326
	q-max (W/cm2)	.240(a)	1.065	.310	.306	.855
	Water Vapor Transmission Rate (g/hr.m2)	-.368(a)	-1.772	.104	-.471	.860
	Wicking level (cm) at 5 mins	-.314(a)	-1.586	.141	-.431	.994
	Moisture Regain (%)	-.037(a)	-.154	.880	-.046	.813
	Thermal insulation by Walter (m2oC/w)	-.366(a)	-1.938	.079	-.505	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.303(a)	1.077	.305	.309	.545

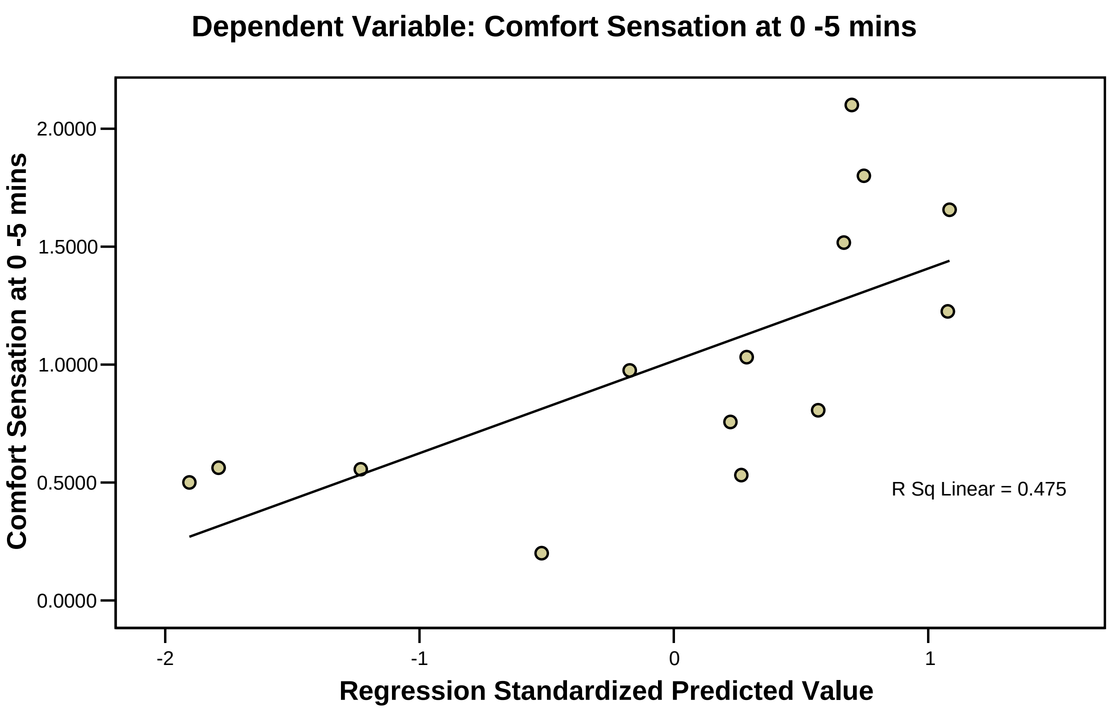
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 0 -5 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.270012	1.439793	1.015475	.3914062	14
Residual	-.6120728	.8106782	.0000000	.4113655	14
Std. Predicted Value	-1.905	1.084	.000	1.000	14
Std. Residual	-1.430	1.893	.000	.961	14

a Dependent Variable: Comfort Sensation at 0 -5 mins

Scatterplot



(B) In the middle of exercise

N-4) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thermal insulation (clo)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Water Vapour Resistance by Walter (m2Pa/w)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.777(a)	.604	.571	.1370391
2	.855(b)	.732	.683	.1177597

a Predictors: (Constant), thermal insulation (clo)
b Predictors: (Constant), thermal insulation (clo), Water Vapour Resistance by Walter (m2Pa/w)
c Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.343	1	.343	18.268	.001(a)
	Residual	.225	12	.019		
	Total	.568	13			
2	Regression	.416	2	.208	14.995	.001(b)
	Residual	.153	11	.014		
	Total	.568	13			

a Predictors: (Constant), thermal insulation (clo)
b Predictors: (Constant), thermal insulation (clo), Water Vapour Resistance by Walter (m2Pa/w)
c Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.122	.200		-.611	.553
	thermal insulation (clo)	10.543	2.467	.777	4.274	.001
2	(Constant)	-2.513	1.057		-2.377	.037
	thermal insulation (clo)	8.076	2.377	.595	3.397	.006
	Water Vapour Resistance by Walter (m2Pa/w)	.116	.051	.401	2.291	.043

a Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	.232(a)	1.312	.216	.368	.999
	thickness (mm)	.379(a)	1.214	.250	.344	.326
	Air Permeability (cm3/s/cm2)	-.303(a)	-1.728	.112	-.462	.921
	q-max (W/cm2)	.066(a)	.220	.830	.066	.397
	Water Vapor Transmission Rate (g/hr.m2)	-.198(a)	-1.096	.297	-.314	.995
	Wicking level (cm) at 5 mins	-.163(a)	-.832	.423	-.243	.879
	Moisture Regain (%)	.117(a)	.627	.544	.186	.999
	Thermal insulation by Walter (m2oC/w)	.019(a)	.102	.921	.031	.988
	Water Vapour Resistance by Walter (m2Pa/w)	.401(a)	2.291	.043	.568	.795
2	mass per unit area (g/m2)	.050(b)	.255	.804	.080	.696
	thickness (mm)	.009(b)	.024	.981	.008	.210
	Air Permeability (cm3/s/cm2)	-.172(b)	-.941	.369	-.285	.741
	q-max (W/cm2)	-.160(b)	-.585	.572	-.182	.345
	Water Vapor Transmission Rate (g/hr.m2)	.315(b)	1.145	.279	.340	.313
	Wicking level (cm) at 5 mins	.082(b)	.386	.708	.121	.591
	Moisture Regain (%)	.058(b)	.350	.733	.110	.971
	Thermal insulation by Walter (m2oC/w)	.251(b)	1.470	.172	.421	.759

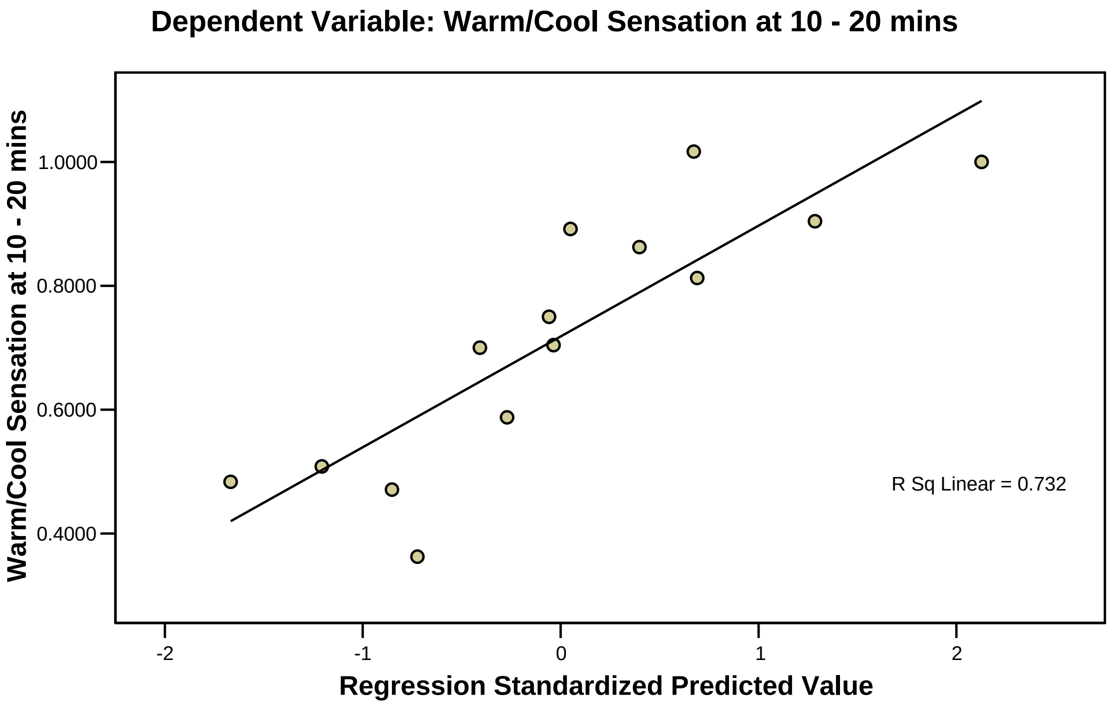
a Predictors in the Model: (Constant), thermal insulation (clo)
b Predictors in the Model: (Constant), thermal insulation (clo), Water Vapour Resistance by Walter (m2Pa/w)
c Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.419856	1.098626	.718155	.1788603	14
Residual	-.2261946	.1782076	.0000000	.1083232	14
Std. Predicted Value	-1.668	2.127	.000	1.000	14
Std. Residual	-1.921	1.513	.000	.920	14

a Dependent Variable: Warm/Cool Sensation at 10 - 20 mins

Scatterplot



N-5) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thermal insulation (clo)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.804(a)	.647	.618	.1271876

a Predictors: (Constant), thermal insulation (clo)
b Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.356	1	.356	22.009	.001(a)
	Residual	.194	12	.016		
	Total	.550	13			

a Predictors: (Constant), thermal insulation (clo)
b Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.582	.186		-3.135	.009
	thermal insulation (clo)	10.740	2.289	.804	4.691	.001

a Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.013(a)	-.072	.944	-.022	.999
	thickness (mm)	.196(a)	.637	.537	.189	.326
	Air Permeability (cm3/s/cm2)	-.001(a)	-.005	.996	-.002	.921
	q-max (W/cm2)	.146(a)	.520	.613	.155	.397
	Water Vapor Transmission Rate (g/hr.m2)	-.071(a)	-.396	.700	-.119	.995
	Wicking level (cm) at 5 mins	-.130(a)	-.696	.501	-.205	.879
	Moisture Regain (%)	.034(a)	.189	.854	.057	.999
	Thermal insulation by Walter (m2oC/w)	-.195(a)	-1.147	.276	-.327	.988
	Water Vapour Resistance by Walter (m2Pa/w)	.240(a)	1.279	.227	.360	.795

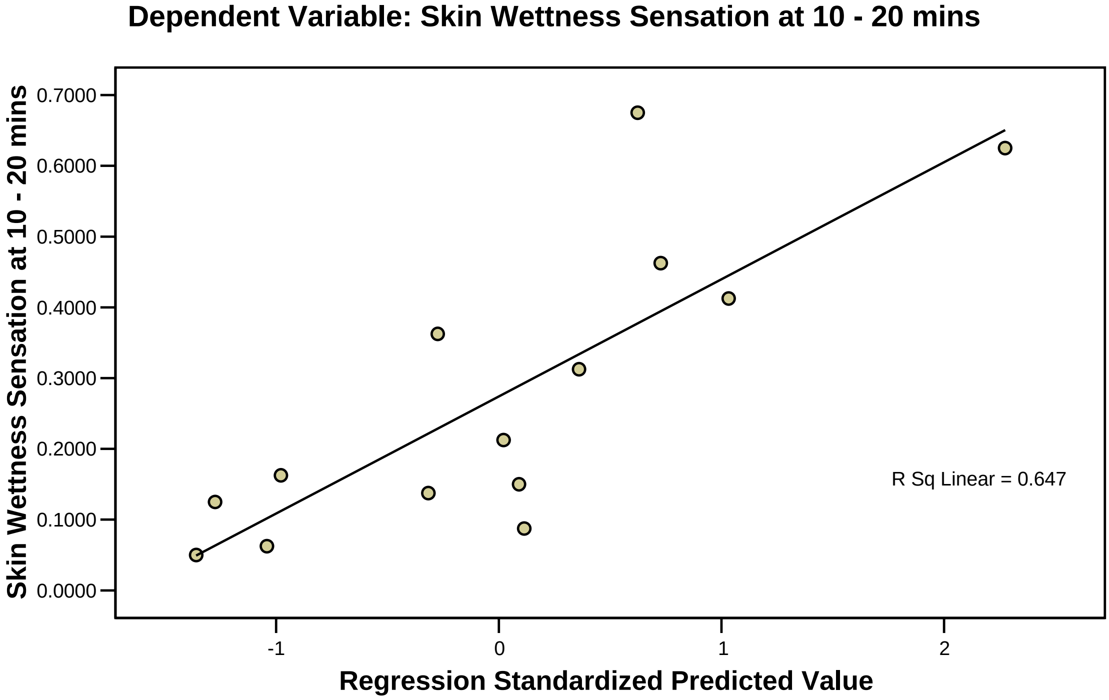
a Predictors in the Model: (Constant), thermal insulation (clo)
b Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.049140	.650491	.274107	.1654887	14
Residual	-.2055018	.2976870	.0000000	.1221979	14
Std. Predicted Value	-1.359	2.274	.000	1.000	14
Std. Residual	-1.616	2.341	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 10 - 20 mins

Scatterplot



N-6) Regression (Overall Comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.720(a)	.518	.478	.3453004

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 10 - 20 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.537	1	1.537	12.895	.004(a)
	Residual	1.431	12	.119		
	Total	2.968	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 10 - 20 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.904	.422		4.516	.001
	thickness (mm)	-1.991	.554	-.720	-3.591	.004

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.101(a)	-.437	.671	-.131	.800
	Air Permeability (cm3/s/cm2)	.091(a)	.435	.672	.130	.982
	thermal insulation (clo)	-.380(a)	-1.090	.299	-.312	.326
	q-max (W/cm2)	.265(a)	1.250	.237	.353	.855
	Water Vapor Transmission Rate (g/hr.m2)	-.258(a)	-1.216	.249	-.344	.860
	Wicking level (cm) at 5 mins	-.190(a)	-.943	.366	-.274	.994
	Moisture Regain (%)	.129(a)	.563	.585	.167	.813
	Thermal insulation by Walter (m2oC/w)	-.245(a)	-1.253	.236	-.354	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.086(a)	.304	.767	.091	.545

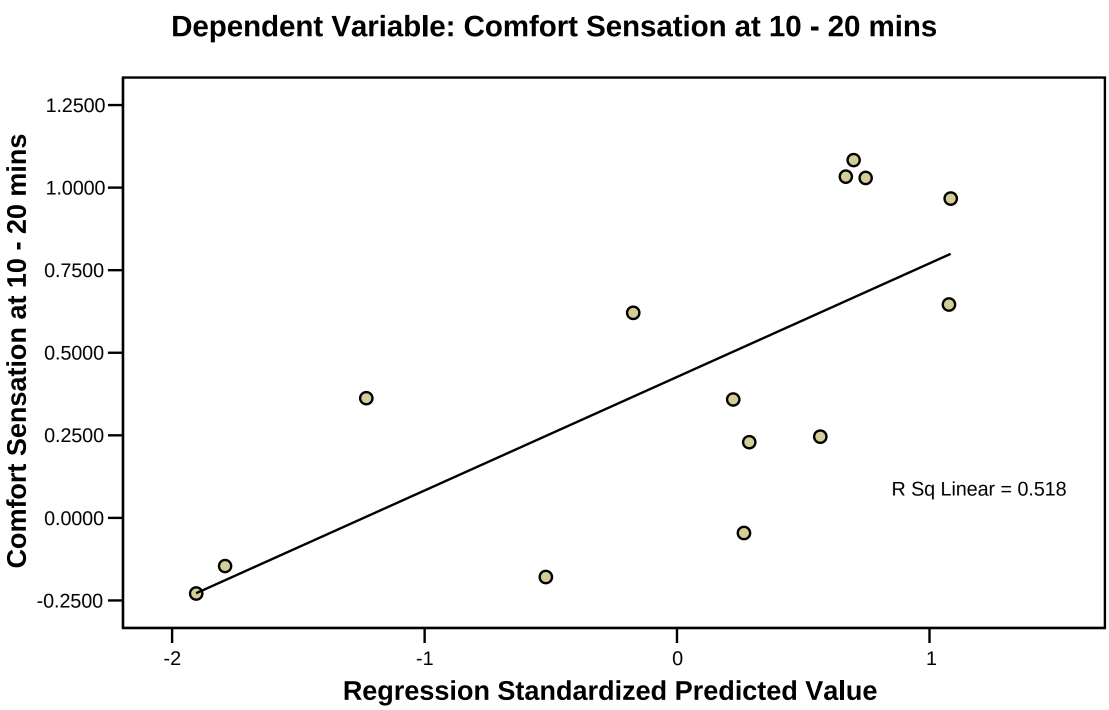
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 10 - 20 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.228196	.799602	.426786	.3438991	14
Residual	-.5638961	.4159390	.0000000	.3317538	14
Std. Predicted Value	-1.905	1.084	.000	1.000	14
Std. Residual	-1.633	1.205	.000	.961	14

a Dependent Variable: Comfort Sensation at 10 - 20 mins

Scatterplot



(C) At the end of exercise

N-7) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Warm/Cool Sensation at 30 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.588(a)	.346	.291	.2309012

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Warm/Cool Sensation at 30 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.338	1	.338	6.338	.027(a)
	Residual	.640	12	.053		
	Total	.978	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Warm/Cool Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.600	.282		2.129	.055
	thickness (mm)	.933	.371	.588	2.518	.027

a Dependent Variable: Warm/Cool Sensation at 30 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.244(a)	-.930	.372	-.270	.800
	Air Permeability (cm3/s/cm2)	-.080(a)	-.326	.751	-.098	.982
	thermal insulation (clo)	.246(a)	.585	.571	.174	.326
	q-max (W/cm2)	-.243(a)	-.959	.358	-.278	.855
	Water Vapor Transmission Rate (g/hr.m2)	.094(a)	.361	.725	.108	.860
	Wicking level (cm) at 5 mins	.099(a)	.408	.691	.122	.994
	Moisture Regain (%)	-.130(a)	-.484	.638	-.144	.813
	Thermal insulation by Walter (m2oC/w)	-.092(a)	-.379	.712	-.113	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.210(a)	.649	.530	.192	.545

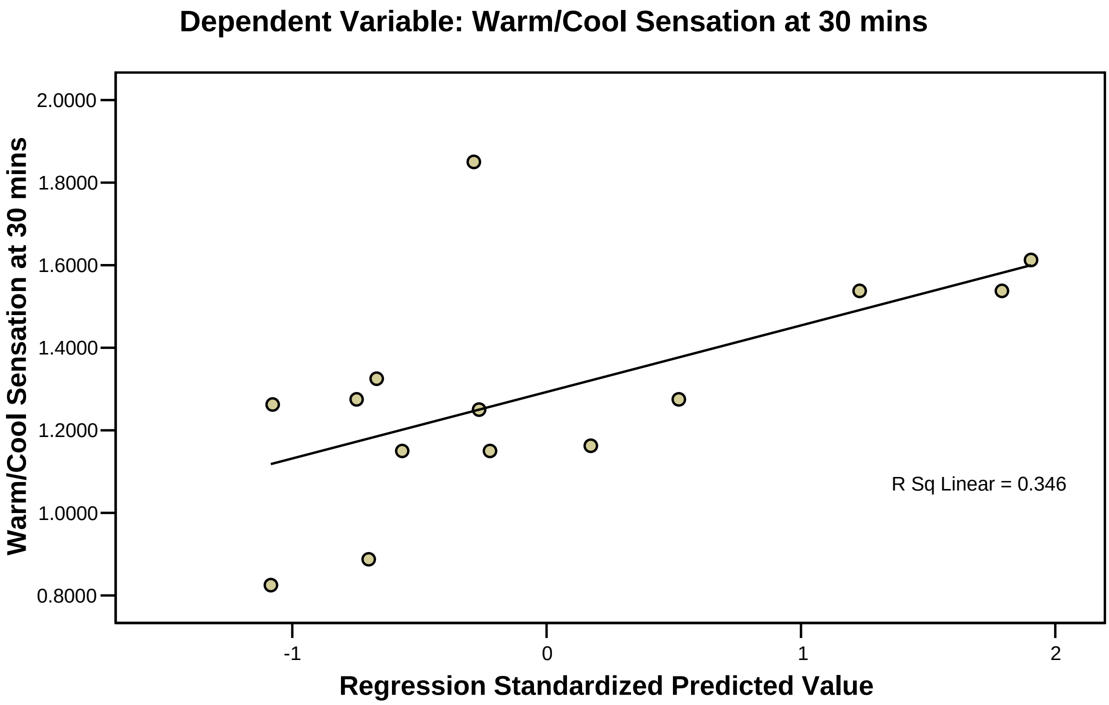
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Warm/Cool Sensation at 30 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.118069	1.599933	1.292857	.1612306	14
Residual	-.2930691	.6032969	.0000000	.2218427	14
Std. Predicted Value	-1.084	1.905	.000	1.000	14
Std. Residual	-1.269	2.613	.000	.961	14

a Dependent Variable: Warm/Cool Sensation at 30 mins

Scatterplot



<u>N-8) Regression (skin wetness sensation)</u>

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Skin Wettness Sensation at 30 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.655(a)	.429	.382	.2689641

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 30 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.653	1	.653	9.032	.011(a)
	Residual	.868	12	.072		
	Total	1.521	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.381	.328		1.159	.269
	thickness (mm)	1.298	.432	.655	3.005	.011

a Dependent Variable: Skin Wettness Sensation at 30 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.223(a)	-.908	.383	-.264	.800
	Air Permeability (cm3/s/cm2)	-.041(a)	-.180	.861	-.054	.982
	thermal insulation (clo)	.183(a)	.463	.652	.138	.326
	q-max (W/cm2)	-.187(a)	-.779	.453	-.229	.855
	Water Vapor Transmission Rate (g/hr.m2)	.158(a)	.656	.525	.194	.860
	Wicking level (cm) at 5 mins	.110(a)	.488	.635	.145	.994
	Moisture Regain (%)	-.085(a)	-.338	.742	-.101	.813
	Thermal insulation by Walter (m2oC/w)	.058(a)	.256	.802	.077	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.080(a)	.261	.799	.079	.545

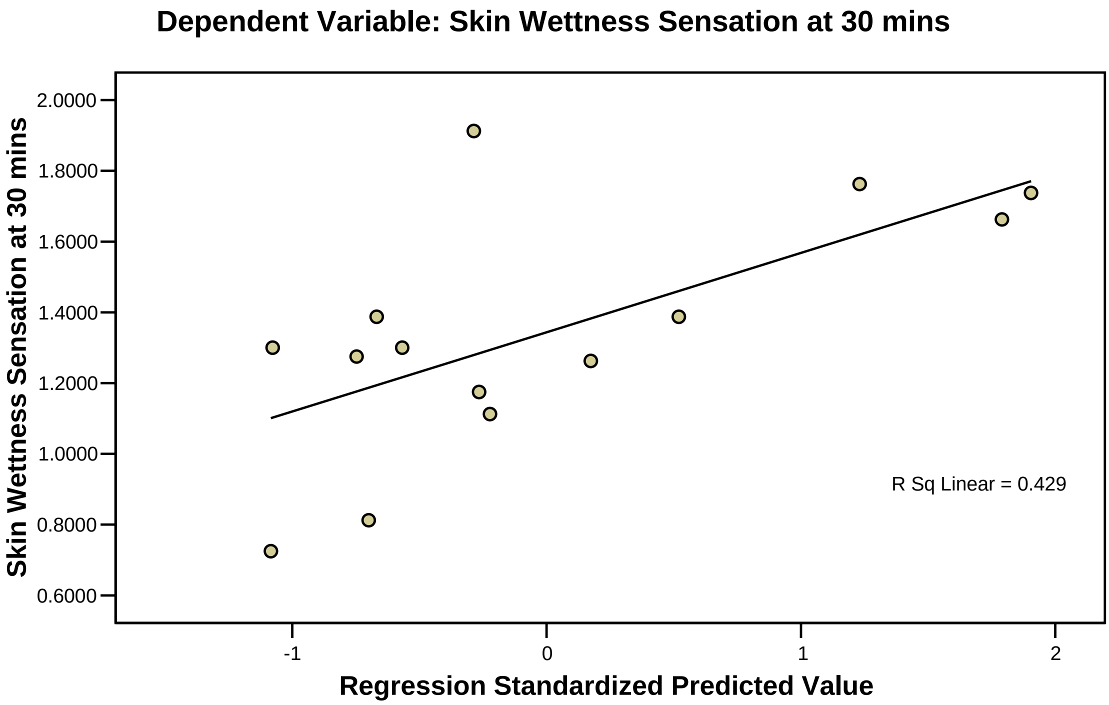
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 30 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.100710	1.770733	1.343750	.2241882	14
Residual	-.3757104	.6329264	.0000000	.2584123	14
Std. Predicted Value	-1.084	1.905	.000	1.000	14
Std. Residual	-1.397	2.353	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 30 mins

Scatterplot



N-9) Regression (Overall Comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 30 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.759(a)	.576	.541	.3238837

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 30 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.713	1	1.713	16.327	.002(a)
	Residual	1.259	12	.105		
	Total	2.971	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 30 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.641	.396		4.148	.001
	thickness (mm)	-2.101	.520	-.759	-4.041	.002

a Dependent Variable: Comfort Sensation at 30 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.281(a)	-1.386	.193	-.385	.800
	Air Permeability (cm3/s/cm2)	.291(a)	1.638	.130	.443	.982
	thermal insulation (clo)	.042(a)	.123	.904	.037	.326
	q-max (W/cm2)	.039(a)	.186	.856	.056	.855
	Water Vapor Transmission Rate (g/hr.m2)	.051(a)	.242	.813	.073	.860
	Wicking level (cm) at 5 mins	-.053(a)	-.271	.791	-.081	.994
	Moisture Regain (%)	.081(a)	.374	.716	.112	.813
	Thermal insulation by Walter (m2oC/w)	-.044(a)	-.226	.826	-.068	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	-.291(a)	-1.161	.270	-.330	.545

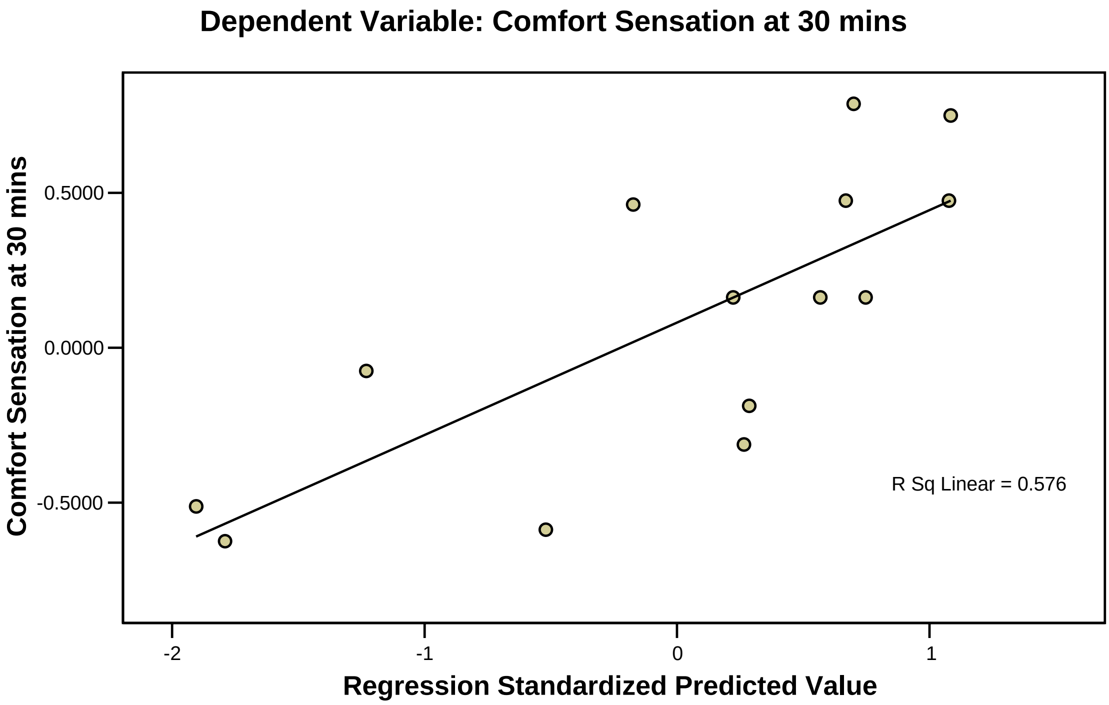
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Comfort Sensation at 30 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.610046	.474737	.081250	.3629660	14
Residual	-.4900878	.4523013	.0000000	.3111774	14
Std. Predicted Value	-1.905	1.084	.000	1.000	14
Std. Residual	-1.513	1.396	.000	.961	14

a Dependent Variable: Comfort Sensation at 30 mins

Scatterplot



(D) After exercise

N-10) Regression (warmth sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	Water Vapour Resistance by Walter (m2Pa/w)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).
2	Thermal insulation by Walter (m2oC/w)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .100, Probability-of-F-to-remove >= .200).

a Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.474(a)	.225	.160	.1814863
2	.648(b)	.420	.314	.1640331

a Predictors: (Constant), Water Vapour Resistance by Walter (m2Pa/w)
b Predictors: (Constant), Water Vapour Resistance by Walter (m2Pa/w), Thermal insulation by Walter (m2oC/w)
c Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.115	1	.115	3.485	.087(a)
	Residual	.395	12	.033		
	Total	.510	13			
2	Regression	.214	2	.107	3.978	.050(b)
	Residual	.296	11	.027		
	Total	.510	13			

a Predictors: (Constant), Water Vapour Resistance by Walter (m2Pa/w)
b Predictors: (Constant), Water Vapour Resistance by Walter (m2Pa/w), Thermal insulation by Walter (m2oC/w)
c Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.665	1.552		-1.717	.112
	Water Vapour Resistance by Walter (m2Pa/w)	.130	.070	.474	1.867	.087
2	(Constant)	-5.243	1.942		-2.700	.021
	Water Vapour Resistance by Walter (m2Pa/w)	.180	.068	.654	2.637	.023
	Thermal insulation by Walter (m2oC/w)	7.984	4.157	.476	1.921	.081

a Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	.162(a)	.531	.606	.158	.743
	thickness (mm)	.239(a)	.678	.512	.200	.545
	Air Permeability (cm3/s/cm2)	-.301(a)	-1.162	.270	-.331	.937
	thermal insulation (clo)	.132(a)	.446	.664	.133	.795
	q-max (W/cm2)	-.156(a)	-.588	.568	-.175	.978
	Water Vapor Transmission Rate (g/hr.m2)	.453(a)	1.157	.272	.330	.409
	Wicking level (cm) at 5 mins	.106(a)	.380	.711	.114	.897
	Moisture Regain (%)	.113(a)	.425	.679	.127	.981
	Thermal insulation by Walter (m2oC/w)	.476(a)	1.921	.081	.501	.858
2	mass per unit area (g/m2)	.006(b)	.021	.984	.007	.674
	thickness (mm)	.024(b)	.067	.948	.021	.472
	Air Permeability (cm3/s/cm2)	-.377(b)	-1.701	.120	-.474	.916
	thermal insulation (clo)	-.041(b)	-.142	.890	-.045	.704
	q-max (W/cm2)	-.041(b)	-.162	.874	-.051	.910
	Water Vapor Transmission Rate (g/hr.m2)	.366(b)	1.010	.336	.304	.402
	Wicking level (cm) at 5 mins	.013(b)	.051	.961	.016	.861
	Moisture Regain (%)	.149(b)	.624	.546	.194	.974

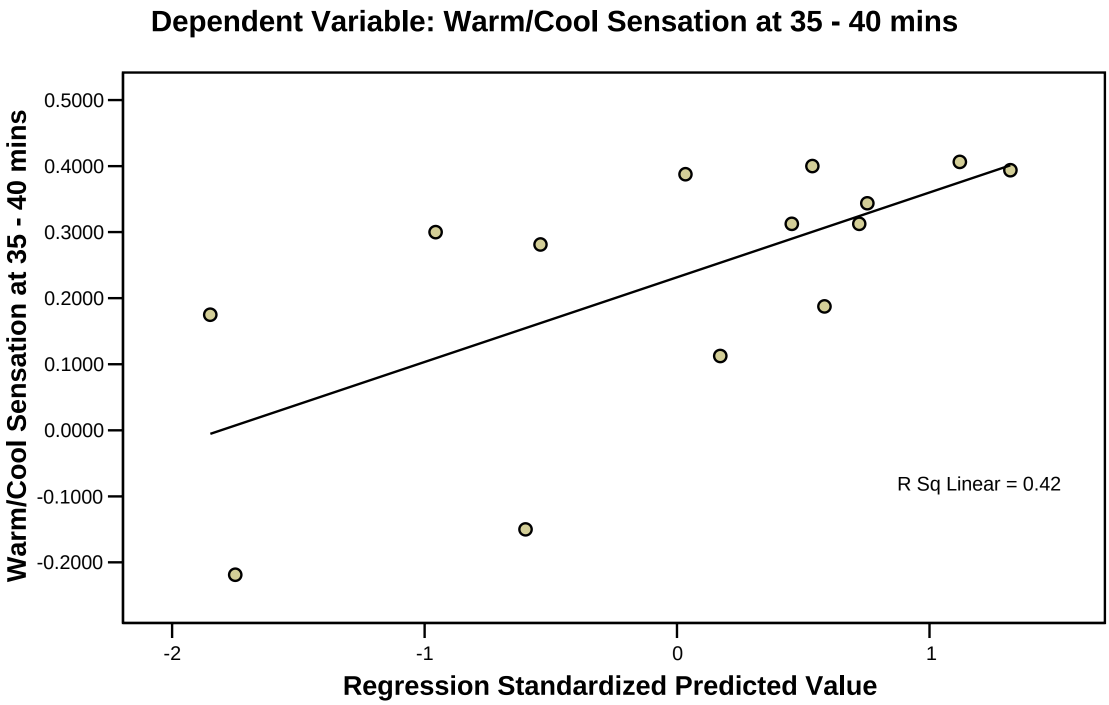
a Predictors in the Model: (Constant), Water Vapour Resistance by Walter (m2Pa/w)
b Predictors in the Model: (Constant), Water Vapour Resistance by Walter (m2Pa/w), Thermal insulation by Walter (m2oC/w)
c Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.005531	.401112	.231696	.1283208	14
Residual	-.3046974	.1910151	.0000000	.1508885	14
Std. Predicted Value	-1.849	1.320	.000	1.000	14
Std. Residual	-1.858	1.164	.000	.920	14

a Dependent Variable: Warm/Cool Sensation at 35 - 40 mins

Scatterplot



N-11) Regression (skin wetness sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .200, Probability-of-F-to-remove >= .300).

a Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.527(a)	.277	.217	.2366502

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.258	1	.258	4.608	.053(a)
	Residual	.672	12	.056		
	Total	.930	13			

a Predictors: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.381	.289		-1.318	.212
	thickness (mm)	.816	.380	.527	2.147	.053

a Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	.090(a)	.314	.759	.094	.800
	Air Permeability (cm3/s/cm2)	-.323(a)	-1.349	.204	-.377	.982
	thermal insulation (clo)	-.196(a)	-.440	.668	-.132	.326
	q-max (W/cm2)	-.046(a)	-.167	.870	-.050	.855
	Water Vapor Transmission Rate (g/hr.m2)	.014(a)	.050	.961	.015	.860
	Wicking level (cm) at 5 mins	-.036(a)	-.139	.892	-.042	.994
	Moisture Regain (%)	.055(a)	.194	.850	.058	.813
	Thermal insulation by Walter (m2oC/w)	.165(a)	.654	.526	.194	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	.182(a)	.532	.605	.158	.545

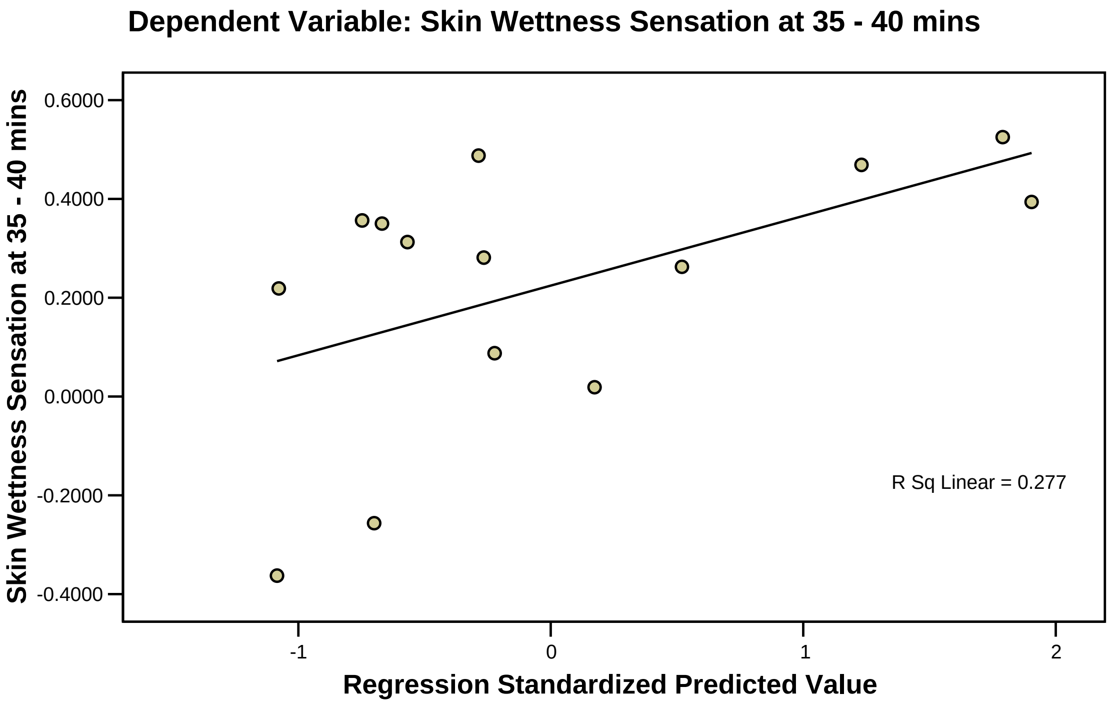
a Predictors in the Model: (Constant), thickness (mm)
b Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.071809	.492902	.224554	.1408968	14
Residual	-.4343092	.3032797	.0000000	.2273661	14
Std. Predicted Value	-1.084	1.905	.000	1.000	14
Std. Residual	-1.835	1.282	.000	.961	14

a Dependent Variable: Skin Wettness Sensation at 35 - 40 mins

Scatterplot



N-12) Regression (Overall Comfort sensation)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	thickness (mm)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Air Permeability (cm3/s/cm2)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.716(a)	.513	.473	.3773352
2	.870(b)	.757	.712	.2786992

a Predictors: (Constant), thickness (mm)
b Predictors: (Constant), thickness (mm), Air Permeability (cm3/s/cm2)
c Dependent Variable: Comfort Sensation at 35 - 40 mins

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.800	1	1.800	12.645	.004(a)
	Residual	1.709	12	.142		
	Total	3.509	13			
2	Regression	2.655	2	1.327	17.088	.000(b)
	Residual	.854	11	.078		
	Total	3.509	13			

a Predictors: (Constant), thickness (mm)
b Predictors: (Constant), thickness (mm), Air Permeability (cm3/s/cm2)
c Dependent Variable: Comfort Sensation at 35 - 40 mins

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.268	.461		4.922	.000
	thickness (mm)	-2.155	.606	-.716	-3.556	.004
2	(Constant)	1.616	.393		4.110	.002
	thickness (mm)	-1.954	.452	-.650	-4.326	.001
	Air Permeability (cm3/s/cm2)	.004	.001	.498	3.316	.007

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	mass per unit area (g/m2)	-.413(a)	-2.068	.063	-.529	.800
	Air Permeability (cm3/s/cm2)	.498(a)	3.316	.007	.707	.982
	thermal insulation (clo)	.345(a)	.976	.350	.282	.326
	q-max (W/cm2)	-.092(a)	-.406	.693	-.122	.855
	Water Vapor Transmission Rate (g/hr.m2)	.155(a)	.699	.499	.206	.860
	Wicking level (cm) at 5 mins	.160(a)	.779	.453	.229	.994
	Moisture Regain (%)	-.154(a)	-.673	.515	-.199	.813
	Thermal insulation by Walter (m2oC/w)	.200(a)	.990	.344	.286	1.000
	Water Vapour Resistance by Walter (m2Pa/w)	-.316(a)	-1.175	.265	-.334	.545
2	mass per unit area (g/m2)	-.042(b)	-.170	.868	-.054	.396
	thermal insulation (clo)	-.483(b)	-1.395	.193	-.404	.170
	q-max (W/cm2)	.316(b)	1.762	.109	.487	.576
	Water Vapor Transmission Rate (g/hr.m2)	-.060(b)	-.332	.746	-.105	.731
	Wicking level (cm) at 5 mins	-.072(b)	-.419	.684	-.131	.801
	Moisture Regain (%)	.280(b)	1.408	.189	.407	.515
	Thermal insulation by Walter (m2oC/w)	.091(b)	.576	.578	.179	.947
	Water Vapour Resistance by Walter (m2Pa/w)	-.177(b)	-.845	.418	-.258	.518

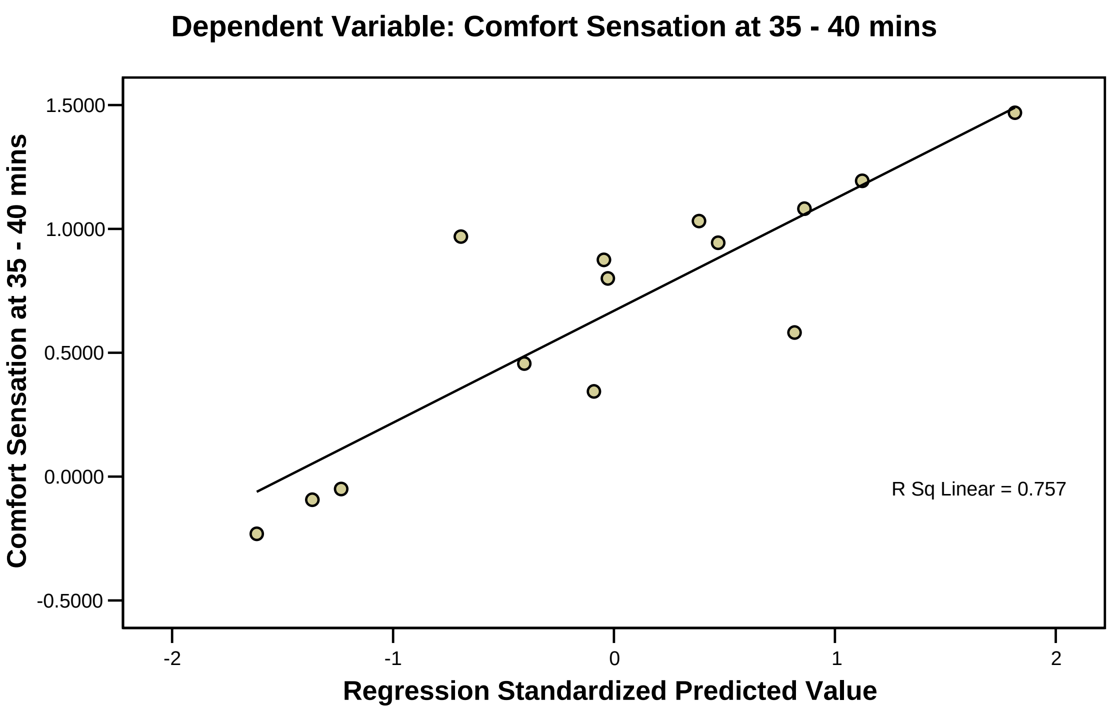
a Predictors in the Model: (Constant), thickness (mm)
b Predictors in the Model: (Constant), thickness (mm), Air Permeability (cm3/s/cm2)
c Dependent Variable: Comfort Sensation at 35 - 40 mins

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-.061371	1.489607	.669196	.4518862	14
Residual	-.4575250	.6124071	.0000000	.2563660	14
Std. Predicted Value	-1.617	1.816	.000	1.000	14
Std. Residual	-1.642	2.197	.000	.920	14

a Dependent Variable: Comfort Sensation at 35 - 40 mins

Scatterplot



REFERENCES

1. Cheng, K. P. S. and Cheung, Y. K., ‘Comfort in Clothing’, *Textile Asia*, 1994 **25**(2): 48-52.

2. Qian, Xiaoming., ‘Prediction of Clothing Thermal Insulation and Moisture Vapour Resistance’, *Hong Kong Polytechnic University, PhD. Thesis*, April 2005.

3. Spencer-Smith, J. L., ‘The Physical Basis of Clothing Comfort – Part 1: General Review’, *Clothing Research Journal*, 1976, **4** (3): 126 – 138.

4. Bejan, A., ‘Heat Transfer’, *John Wiley & Sons, Inc.*, Canada, 1993.

5. Dorkin, C. M. C. and Beever, D. K., ‘The Physical Basis of Clothing Comfort’, *Clothing Research Journal*, 1997, **5** (1).

6. Ingram, D. L., Mount, L.E., ‘Heat Exchange Between Animal and Environment. In: Schaefer KE (ed) Man and animals in hot environments’, Springer, Berlin Heidelberg New York, 1975, 5-23.

7. Kwon, A., Kato, M., Kawamura, H., Yanai, Y. and Tokura, H., ‘Physiological Significance of Hydrophilic and Hydrophobic Textile Materials during Intermittent Exercise in Humans under the Influence of Warm Ambient Temperature with and without Wind’, *European Journal of Applied Physiology*, 1998, **78** 487-493.

8. Fuzek, J. F., “Some Factors Affecting the Comfort Assessment of Knit T-shirts”, *Industrial and Engineering Chemistry – Product Research and Development*, 1981, 20(2): 254-259.

9. DeMartino, R. N., Yoon, H. N. and Buckley, A., “Improved Comfort Polyester – Part V: Results from Two Subjective Wearer Trials and Their Correlation with Laboratory Tests”, *Textile Research Journal*, 1984, 54(9): 602-613.

10. Scheurell, D. M., Spivak, S. M. and Hollies, N. R. S., “Dynamic Surface Wetness of Fabrics in Relation to Clothing Comfort”, *Textile Research Journal*, 1985, 55(7): 394-399.

11. Li, Y., Keighley, J. H., McIntyre, J. E. and Hampton, I. F. G., “Predictability Between Objective Physical Factors of Fabrics and Subjective Preference Votes for Derived Garments”, *Journal of the Textile Institute*, 1991, 82 (3): 277-284.

12. Yoo, S. and Barker, R. L., “Comfort Properties of Heat Resistant Protective Workwear in Varying Conditions of Physical Activity and Environment. Part II: Preceived Comfort Response to Garments and its Relationship to Fabric Properties”, *Textile Research Journal*, 2005, 75(7): 531-541.

13. Ishtiaque, S. M., ‘Engineering Comfort’, *Asian Textile Journal*, 2001, **10**(11): 36-39.

14. Zhong, Wang, ‘Heat and Moisture Transfer and Clothing Thermal Comfort’, PhD Thesis, The Hong Kong Polytechnic University, 2002.

15. Gagge, A. P., Stolwijk, J. A. J. and Hardy, J. D., ‘Comfort and Thermal Sensations and Associated Physiological Responses at Various Ambient Temperatures’, *Environmental Research*, 1969, **2** 209-229.

16. Chen, Y. S., ‘The Development of a Perspiring Fabric Manikin for the Evaluation of Clothing Thermal Comfort’, *The Hong Kong Polytechnic University, PhD. Thesis*, 2003.

17. Hatch, K. L., ‘Textile Science’, *West Publishing Company*, New York, NY, USA, 1993.

18. Fanger, P. O., ‘Thermal Comfort’, *Copenhagen: Danish Technical Press*, 1970.

19. Hollies, N. R. S., ‘Psychological Scaling in Comfort Assessment. In: Hollies NRS, Goldman RF (eds) Clothing Comfort: Interaction of Thermal, Ventilation, Construction and Assessment Factors’, *Ann Arbor Science*, Ann Arbor, Mich., 1977, 107-120.

20. Hardy, H. B., Jr., Ballou, J. W. and Wetmore, O. C., ‘The Prediction of Equilibrium Thermal Comfort from Physical Data on Fabrics’, *Textile Res. J.*, 1953, **23**(1): 1-10.

21. Mehrtens, D. G. and McAlister K. C., ‘Fiber Properties Responsible for Garment Comfort’, *Textile Research Journal*, 1962, **32**(8): 658-665.

22. Nielsen, R. and Endrusick, T. L., ‘Sensations of Temperature and Humidity During Alternative Work/Rest and the Influence of Underwear Knit Structure’, *Ergonomics*, 1990 **33**(2): 221-234.

23. Ampuero, J. and Derler, S., ‘Skin Friction Management, an Emerging Apparel and Textile Science’, *Textile Asia*, 2002, **33** (8): 28-32.

24. Laing, R. M. and Slivert, G. G., ‘Clothing, Textiles and Human Performance: A Critical Review of the Effect of Human Performance of Clothing and Textiles’, *Textile Institute*, 2002, **32**(2): 1-122.

25. Hyun, S. O., ‘Skin Sensations Perceived in Apparel Wear Under Varying Conditions’, *Ph. D. Thesis*, University of Maryland, Ann Arbor, Mich.; U.M.I., 1989.

26. Ruckman, J. E. and Gree, J. A., ‘Comfort of Shirts for Distance Runners’, *Journal of Clothing Tech. & Mgt.*, 1996 **13**(1): 1-25.

27. Sweeney, M. M. and Branson, D. H., ‘Sensorial Comfort – Part I: A Psychological Method for Assessing Moisture Sensation in Clothing’, *Text. Res. J.*, 1990, **60**(7): 371-337.

28. Winslow, C. E. A., Herrington, L. P. and Gagge, A. P., ‘Relations between Atmospheric Conditions, Physiological Reactions and Sensations of Pleasantness’, *American Journal of Hygiene*, 1937 **26** 103-115.

29. Hollies N R S, ‘Visual and Tactile Perceptions of Textile Quality’, *J. Text. Inst.*, 1989 **80**(1): 1-18.

30. Boslet, R. J., ‘Why Cotton Sells’, *Textile Asia*, 1989 **20**(12): 161.

31. Byrne, M. S., Gardner, A. P. W. and Fritz, A. M., ‘Fibre Types and End-Uses: A Perceptual Study’, *J. Text. Inst.*, 1993 **84**(2): 275-288.

32. Chapman, R., ‘Weaving Yarns ‘80’, *Text. Month*, 1980 **March** 31-45.

33. Godehn, D. J., 'Golden – Touch Polyester – A New Dimension in Polyester Yarn', *Lenzinger Ber.*, 1979, **47**(5): 151-158.

34. Korner, W., Blankenstein, G., Dorsch, P. and Reinehr, U., 'Dunova, an Absorbent Synthetic Fibre for High Wear Comfort', *Chemiefasern/Textilindustrie*, 1979, **29/81**(6): 452-462-+-E62-65.

35. Vokac, Z., 'Physiological Responses and Thermal, Humidity, and Comfort Sensations in Wear Trials with Cotton and Polypropylene Vests', *Text. Res. J.*, 1976, **46**(1): 30-38.

36. Gavin, T. P., Babington, J. P., Harms, C. A., Ardelt, M. E., Tanner, D. A. and Stager, J. M., 'Clothing Fabric does not Affect Thermoregulation During Exercise in Moderate Heat', *Medicine & Science in Sports & Exercise*, 2001 Dec, **33** (12): 2124-2130.

37. Amato, M. R., 'Experimental Psychology, Methodology, Psychophysicas, and Learning', 1970, New York: McGraw-HILL Company.

38. Merkel, R. S. and Miller, I. B., 'Recommendations for Investigating the Degree of Correlation Between Lab Tests and Wear Tests', *Textile Chemist and Colorist*, 1987 **19**(4): 23-25.

39. Parsons, K.C., 'Human Thermal Environments – The effects of hot, moderate and cold environments on human health, comfort and performance', London ; Bristol, Pa. : Taylor & Francis, 1993.

40. Fuzek, J. F. and Ammons, R. L., 'Techniques for the Subjective Assessment of Comfort in Fabrics and Garments', *Ann-Arbor-Science-Publishers-Inc.*, Ann-Arbor-(Michigan-48106); 1977, 121-130.

41. Sweeney, M. M. and Branson, D. H., 'Sensorial Comfort, Part II: A Magnitude Estimation Approach for Assessing Moisture Sensaiton', *Textile Research Journal*, 1990, **60** (8): 447 – 452.

42. Gonzalez, R. R. and Gagge, A. P., ‘Magnitude Estimates of Thermal Discomfort During Transients of Humidity and Operative Temperature’, *ASHRAE Transactions*, 1973, **79** (1): 89-96.

43. American Standards for Testing and Materials (ASTM D3181), ‘Standard Guide for Conducting Wear Tests on Textiles’, 2002.

44. Hensel, H., ‘Thermoreception and Temperature Regulation’, London: Academic Press, 1981.

45. Weddel, G. and Miller, S., ‘Cutaneous Sensibility’, *Annual Review of Physiology*, 1962, **24** 199 – 222.

46. Hatch, K. L., Markee, N. L., Maibach, H. I., Barker, R.L., Woo, S. S. and Radhakrishnaiah, P., ‘In Vivo Cutaneous and Perceived Comfort Response to Fabric – Part III: Water Content and Blood Flow in Human Skin Under Garments Worn by Exercising Subjects in a Hot, Humid Environment’, *Textile Research Journal*, 1990, **60**(9): 511-519.

47. George, F., ‘A Transient, 3-D Mathematical Thermal Model for the Clothed Human’, *Ann Arbor, Michigan: U. M. I.*, 1998 3-23.

48. Whelan, M. E., MacHattie, L. E., Goodings, A. C. and Turl, L. H., ‘The Diffusion of Water Vapor through Laminae with Particular Reference to Textile Fabrics’, *Textile Research Journal*, 1955, **25** (3): 197 – 223.

49. Weiner, J. S., ‘The Regional Distribution of Sweating’, *J. Physiol.*, 1945, **104** 32 – 40.

50. Bligh, J., ‘Regulation of Body Temperature in Man and Other Mammals, in A. Shitzer and R. C. Eberhart (Eds)’, *Heat Transfer in Medicine and Biology – analysis and applications*, v. 1, New York: Plenum Press, 15 – 52.

51. Lind, A. R. and Bass, D. E., ‘The Optimal Exposure Time for the Development of Acclimatisation to Heat’, *Federal Proceedings*, 1963, **22** 704 – 708.

52. Rohsenow, W. M., Hartnett, J. P. and Cho, Y. I., 'Handbook of Heat Transfer', *3rd ed. The McGraw-Hill Companies*, Inc., New York, 1998.

53. Winterton, R. H. S., 'Heat Transfer', Oxford university press, 1997, 3-42.

54. Clulow, E.E., 'Thermal Insulation Properties of fabrics, Shirley Institute, 1978, **7**(2): 47-52.

55. Mecheels, J., 'Textiles for Comfort', *Manchester*, 1971.

56. Incropera, F. P. and DeWitt, D. P., 'Fundamentals of Heat and Mass Transfer', *4th ed. John Wiley & Sons, Inc.*, Canada, 1996.

57. Newburgh, L. H., 'Physiology of Heat Regulation and the Science of Clothing', *Hafner Publishing Co.*, New York.

58. Folk, G. E. and Jr., 'Responses to a Hot Environment. In: Textbook of Environmental Physiology', *Lea and Febiger, Philadelphia*, Pa., 1974, 217-277.

59. Watkins, S. M., 'Clothing: The Portable Environment', Ames, IA: Iowa State University Publishers, 1984.

60. Berglund, L. G. and Gonzalez R. R., 'Evaporation of Sweat from Sedentary Man in Humid Environments', *Journal of Applied Physiology*, 1997, 42: 767-772.

61. Thumm, S., "LAD Fluoocarbon Technology for High-Tech Sportswear", *International Textile Bulletin*, January 2000, 60.

62. Woodcock, A. H., 'Moisture Transfer in Textile Systems, Part I', *Textile Research* Journal, 1962, **32** 628-719.

63. Zhang, P. and Gong, R. H., 'Effects of Clothing Material on Thermoregulatory Responses', *Textile Research Journal*, 2002, **72** (1): 83-89.

64. Hyun, S. O., Hollies, N. R. S. and Spivak, S. M., 'Skin Sensations Perceived in Apparel Wear. I. Development of a New Perception Language', *J. Text. Inst.*, 1991 **82**(3): 389-397.

65. DeMartino, R. N., Yoon, H. N., Buckley, A., Evins, C. V., Averell, R. B., Jackson, W. W., Schultz, D. C., Becker, C. L., Booker, H. E. and Hollies, N. R. S., 'Improved Comfort Polyester: Part III: Wearer Trials', *Text. Res. J.*, 1984, **54** (7): 447-458.

66. Mecheels, J., 'Concomitant Heat and Moisture Transmission Properties of Clothing', *Third-Shirley International Seminar, Shirley Institute, Manchester,* 1971.

67. Pause, B., "Measuring the Water Vapor Permeability of Coated Fabrics and Laminates", *Journal of Coated Fabrics*, 1996, 25, April, 311-320.

68. Wehner, J. A., Miller, B. and Rebenfeld, L., "Dynamics of Water Vapor Transmission through Fabric Barriers", *Textile Research Journal*, 1988, 10: 581-592.

69. Brownless, N. J., Anand, S. C., Holmes, D. A. and Rowe, T., 'The Dynamics of Moisture Transportation Part I: The Effect of 'Wicking' on the Thermal Resistance of Single and Multi-layer Fabric Systems', *J. Text. Inst.*, 1996 **87**(1): 172-182.

70. American Standards for Testing and Materials (ASTM D123), 'Standard Terminology Relating to Textiles', 2003.

71. Fourt, L. and Hollies, R. S. H., 'Clothing: Comfort and Function'. *Marcel Dekker, Inc.*, New York, 1970.

72. Fuzek, J. F., 'Some Factors Affecting the Comfort Assessment of Knit Knitted underwear', *Ind. Eng. Chem. Prod. Res. Dev.*, 1981, **20**(2) 254-259.

73. Ghali, K., Ghaddar, N., Harathani, J. and Jones, B., 'Experimental and Numerical Investigation of the Effect of Phase Change Materials on Clothing During Periodic Ventilation', *Textile Res. J.*, 2004, **74**(3): 205-214.

74. Ha, M., Tokura, H. and Yamashita, Y., 'Effect of Two Kinds of Clothing Made from Hydrophobic and Hydrophilic Fabrics on Local Sweating Rates at an Ambient Temperature of 37^{o}C', Ergonomics, 1995, **38** (7): 1445-1455.

75. Hall, J.F. and Poltke, J.W., ‘Effect of Water Content and Compression on Clothing Insulation’, Journal of Applied Physiology, 1956, **8**: 539-545.

76. Nielsen, R. and Endrusick, T.L., ‘The Role of Textiles Materials in Clothing on Thermoregulatory Responses to Intermittent Exercise. In: Aghazadeh F (ed) Trends in Ergonomics / Human Factor V.’, *Elsevier Science,* North-Holland, 1988, 449-456.

77. Smith, B.F. and Block, I., ‘Natural Fiber In: Tauber H (ed) Textile in Perspective’, *Prentice-Hall*, *Englewood Cliffs*, N.J., 1982, 70-156.

78. Smith, J., ‘Comfort of Clothing’, *Textiles*, 1986 **15**(1): 23-27.

79. American Standards for Testing and Materials (ASTM D1909), ‘Standard Table of Commercial Moisture Regains for Textile Fibers’, 2004.

80. Bakkevig, M. K., ‘The Impact of Clothing Textiles and Construction in a Clothing System on Thermoregulatory Responses, Sweat Accumulation and Heat Transport’, *Thesis, University of Trondheim,* 1995.

81. Wang, J.H. and Yasuda, H., ‘Dynamic Water Vapor and Heat Transport Through Layered Fabrics: Part I: Effect of Surface Modification’, *Textile Research Journal*, 1991, **61**(1): 10-20.

82. Yasuda, T., Miyama, M. and Yasuda, H., ‘Dynamic Water Vapor and Heat Transport Through Layered Fabrics, Part II: Effect of the Chemical Nature of Fibers’, *Textile Research Journal*, 1992, **62** (4): 227-235.

83. Grayson, M., ‘Encyclopedia of Textiles, Fibres, and Nonwoven Fabrics’, *Wiley-Interscience*, NY, 1984.

84. Winslow, C. E. A., Herrington, L. P. and Gagge, A. P., ‘A New Method of Partitional Calorimetry’, *Am. J. Physiol.*, 1936, **116** 641 – 655.

85. Kerslake, D. M., 'The Stress of Hot Environments', Monographs of the Physiological Society, 1972, n. 29.

86. Mochida, T., 'Convective and Radiative Heat Transfer Coefficients for the Human Body', *Bulletin of the Faculty of Engineering, Hokkaido University*, 1977, 1-11.

87. Givoni, B. and Goldman, R. F., 'Predicting Rectal Temperature Response to Work, Environment and Clothing', *J. App. Physiol.*, 1972, **32** 812 – 822.

88. International Standard (ISO 7933), 'Ergonomics of the thermal environment Analytical determination and interpretation of heat stress using calculation of the predicted heat strain-Second Edition', the International Organization for Standardization, 2004.

89. International Standard (ISO 9920), 'Ergonomics of the Thermal Environment – Estimation of the Thermal Insulation and Evaporative Resistance of a Clothing Ensemble,' the International Organization for Standardization, 1995.

90. Gagge, A. P., Burton, A. C. and Bazett, H. C., 'A Practical System of Units for the Description of the Heat Exchange of Man with his Environment', *Sceince*, 1941, **94** (2445): 428-430.

91. McCullough, E. A., Jones, B. W., and Zblkowskl, P. J., 'The Effect of Garment Design on the Thermal Insulation Values of Clothing', *ASHRAE Transactions*, 1983, **89** part 2A, 327-352.

92. McCullough, E. A., Jones, B.W., and Huck, J., 'A Comprehensive Data Base for Estimating Clothing Insulation', *ASHRAE Transactions*, 1985, **91** part 2A, 29-47.

93. Wang, L. P. and Li C., "A New Method for Measuring Dynamic Fabric Heat and Moisture Comfort", *Experimental Thermal and Fluid Science*, 2005, 29: 705-714.

94. Jokin, S.M.S., "Dynamic Moisture Vapor Transfer through Textile", *Textile Research Journal*, 1994, 64(2): 112-121.

95. Yasuda, T., Miyama, M. and Yasuda, H., “Dynamic Water Vapor and Heat Transport Through Layered Fabrics”, *Textile Research Journal*, 1992, 62(2): 227-235.

96. Zhu, S. W., “The Clothing Materials”, *Textile Industry Press*, Beijing, 1994.

97. Holmer, I., ‘Thermal Manikin History and Applications’, *European Journal of Applied Physiology*, 2004, **92** (6):614-618.

98. Chen, Y. S., “The Development of a Perspiring Fabric Manikin for the Evaluation of Clothing Thermal Comfort”, *Ph.D. Thesis*, The Hong Kong Polytechnic University, 2003.

99. Kerslake, D. M., ‘A Heated Manikin for Studies of Ventilated Clothing’, 1963, FPRC Memo No 214, MOD London.

100. Fonseca, G. F., ‘Sectional Dry Heat Transfer Properties of Clothing in Wind’, *Tex. Res. J.*, 1975, 45, 30-34.

101. McCullough, E. A., Jones, B. W., and Tamura, T., ‘A Data Base for Determining the Evaporative Resistance of Clothing’, *ASHRAE Transactions*, 1989, 95(2): 316-328.

102. Mecheels, J. and Umbach, K. H., ‘Thermo-physiological Properties of Clothing System’, *Melliand Textiberichte*, 1997, 57, 1029-1032.

103. Olesen, B. W., Sliwinska, E., Madsen, T. H. and Fanger, P. O., ’Effect of Body Posture and Activity on the Thermal Insulation of Clothing: Measurements by a Moveable Thermal Manikin’, *ASHRAE Transaction*, 1982, 88, 791-805.

104. Hanada, K., ‘Studies on the Regional Thermal Resistance of Clothing System (Part 1)’, *J. Japan Res. Assoc. For Text. End-Uses*, 1979.

105. Meinander, H., ‘Extraction of Data from Sweating Manikin Tests’, Proceedings of the Third International Meeing on Thermal Manikin Testing 3IMM, 1999, Oct. 12-13., Stockholm, Sweden, 95-99.

106. Matt, N., ‘Use Sweating Articulated Manikin SAM for Thermophysiological Assessment of Complete Garments’, *Proceedings of the Third International Meeting on Thermal Manikin Testing, at the National Institute for working life*., Oct. 12-13, 1999, Stockholm, Sweden.

107. Dolhan, P. A., “A Comparison of Apparatus Used to Measure Water Vapour Resistance”, *Journal of Coated Fabrics*, 1987, 17, Oct, 96-109.

108. Harnett, P. R. and Mehta, P. N., “A Survey and Comparsion of Laboratory Test Methods for Measuring Wicking”, 1984, *Textile Research Journal*, 54(7): 471-478.

109. Gibson, P. W., “Factors Influencing Steady-State Heat and Water Vapor Transfer Measurements for Clothing Materials”, 1993, *Textile Research Journal*, 63(12): 749-764.

110. Osczevski, R. J. and Dolhan, P. A., “Anomalous Diffusion in a Water-Vapour-Permeable, Waterproof Coating”, *Journal of Coated Fabrics*, 1989, 18, April, 255-258.

111. Farnworth, B. and Lotens, W. A., “Variation of Water Vapour Resistance of Microporous and Hydrophilic Films with Relative Humidity”, *Textile Research Journal*, 1990, 60(1): 50-53.

112. Lomax, G. R., “Hydrophilic Polyurethane Coatings”, *Journal of Coated Fabrics*, 1988, 20:88-107.

113. Williams, J. T., “Physiological Considerations of NBC Protective Clothing”, Cranfield University, PhD Thesis, 1994.

114. Gretton, J. C., Brook, D. B., Dyson, H. M. and Harlock, S. C., “A Correlation between Test Methods Used to Measure Moisture Vapour Transmission through Fabrics”, *Journal of Coated Fabrics*, 1996, 25, April, 301-310.

115. Indushekar, R., Awasthi, P. and Gupta, R. K., “Studies on Test Methods used to Measure Water Vapor Transmission of Fabrics by DSC and Conventional Dish Techniques”, *Journal of Industrial Textiles,* 2005, 34(4): 223-242.

116. http://www.krystalartfield.com/Akwatek/Akwatek.html

117. http://www.fabriclink.com/pk/akwadyne/home.html

118. http://www.dupont.com/coolmax/why_coolmax.html

119. http://www.fabriclink.com/pk/Coolmax/

120. http://www.fetl.com.tw/

121. http://www.dupont.com.tw/dpsbu/Tactel/product/aquator/aquator.htm

122. http://www.nike.com.cn/product/apparel/product.htm

123. Clark, R. P. and Edholm, O. G., "Man and His Thermal Environment", Edward Arnold, London, 1985.

124. Fanger, P. O., "Thermal Comfort", McGraw Hill, New York, 1970.

125. Scheurell, D. M., Spivak, S. M. and Hollies, N. R. S., "Dynamic Surface Wetness of Fabrics in Relation to Clothing Comfort", *Textile Research Journal*, 1985, 55, 394-399.

126. Lubos, H., "Optimisation of Shirt Fabrics' Composition from the Point of View of Their Appearance and Thermal Comfort", *International Journal of Clothing Science and Technology*, 1999, 11(2/3): 105-119.

127. Huang, J. and Xu W., "A New Practical Unit for the Assessment of the Heat Exchange of Human Body with the Environment", *Journal of Thermal Biology*, 2006, 31, 318-322.

128. Andreen, J. H., Gibson, J. W. And Wetmore, O. C., "Fabric Evaluations Based on Physiological Measurement of Comfort", *Textile Research Journal*, 1953, 23(1): 11-22.

129. Nielsen R. and Endrusick, T. L., "Sensations of Temperature and Humidity during Alternative Work/Rest and the Influence of Underwear Knit Structure", *Ergonomics*, 1990, 33(2): 221-234.

130. Wang, Z., Li, Y. and Kwok, Y. L., "Mathematical Simulation of the Perception of Fabric Thermal and Moisture Sensations", *Textile Research Journal*, 2002, 72(4): 327-334.

131. Wong, A. S. W. and Li, Y., "Relationship between Thermophysiological Responses and Psychological Thermal Perception During Exercise Wearing Aerobic Wear", *Journal of Thermal Biology*, 2004, 29: 791-796.

132. Fan, J., Cheng, X. and Chen, Y. S., "An Experimental Investigation of Moisture Absorption and Condensation in Fibrous Insulations under Low Temperature", Experimental Heat Transfer, 2002, June.

133. Saville, B. P., "Physical Testing of Textiles", *Woodhead Publishing Ltd*, 1999, Cambridge, England.

134. Olesen, B. W., ‘How Many Sites Are Necessary to Estimate a Mean Skin Temperature?’, *Thermal Physiology*, 1984, 33-38.