Impact of textiles on the formation and prevention of skin lesions and pressure ulcers

By

Ayyaz Ahmad

August, 2007

A Thesis
Submitted to the Faculty of Graduate Studies Partial Fulfillment of the Requirements for the Degree of

Master of Science

Department of Clothing & Textiles
University of Manitoba
Winnipeg, Manitoba

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

Impact of textiles on the formation and prevention of skin lesions and pressure ulcers

BY

Ayyaz Ahmad

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

MASTER OF SCIENCE

Abstract

Pressure ulcers are a serious international health care problem. Some of the important factors of causing pressure ulcers are pressure, friction/shear, and skin hydration. These factors are also related with textiles. Textiles have a direct constant contact with the human skin in the form of clothing, sheets or towels. Different textile products and skin work as a system to establish a thermal and sensorial state of comfort. Sometimes direct contact and interaction between textiles and skin may cause skin lesions or pressure ulcers.

The skin/fabric interaction includes pressure, friction/shear, and liquid/moisture transport through fabrics. The role of textiles in the formation and prevention of skin lesions and pressure ulceration is over looked or understudied.

The present study is aimed to investigate the physical and physiological interactions between fabric and skin, as well as their impact on formation and prevention of bedsores. Results of this study provide a basis for further research to design and develop fabrics with optimum frictional and moisture transport properties capable of preventing and relieving bedsores.

In this project, a pressure ulcer prevalence survey was conducted at Riverview Health Centre, Winnipeg among long term care residents. Textile products that may be the cause of skin problems of the residents in this health care facility were evaluated and tested. A Kawabata system was used to evaluate surface and frictional properties of fabrics. An air permeability apparatus was used to evaluate air permeability and a S.E.A. Automated Water Vapour Diffusion Apparatus was employed to determine both moisture diffusion and water transportation through fabrics. The results of these experiments demonstrated that fabric structures have significant effects on the frictional properties and breathability of the fabrics, which collectively impact on the formation and prevention of skin problems and ulcerations.

Acknowledgments

The author wishes to express a special thank-you to his advisor, Dr. Wen Zhong, for her detailed and patient guidance and encouragement throughout the study.

Special thanks are also extended to Dr. Martin King, College of Textiles (NCSU), and Dr. Christine Wu, Department of Engineering for their professional assistance and expert advice.

The author would also like to thank the staff of Riverview Health Centre for providing the necessary information to conduct the survey for this research.

A special appreciation is expressed to Dr. Lena Horne and Dr. Tammi Feltham, Department of Textile Sciences for their wise suggestions regarding my direction of study.

Thanks are extended to my family, and friends for their consistent support. Without them I could not have finished this study.

TABLE OF CONTNETS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

The skin is the largest barrier organ of the human body. Usually in an adult it covers the body's surface area of 1.8 square meter and weigh10 kg (Elsner, 2003). It serves many functions in its role as the external wrapping for the body. It protects the body from a relatively hostile environment and conserves the internal environment with in its narrow variability range. It performs its function as a defense shield against infections. It also functions as the human body's radiator which is the most significant thermoregulatory system factor. A large part of an individual's skin is in constant contact with fabric. The clothing system for example provides an extra layer(s) of barrier to enhance the aesthetics, thermo physiological and sensorial comfort of the wearer. Other fabrics in contact with the skin can be beddings and towels.

However, direct contact and interactions between textiles and skin may cause reactions, even damage or disease, including dermatitis, blisters or pressure ulcers.

1.1 Problem Statement

Pressure ulcers are also known as bedsores or decubitis ulcers. They are defined as an area of localized damage to the skin and underlying tissue caused by pressure, shear, friction, moisture or a combination of these (EPUAP 1999). Pressure ulcers develop when the skin and underlying tissue is squeezed between a bone and an external surface, such as a bed or chair. The most common places for pressure ulcers are over bony prominences (bones close to the skin), such as the elbow, heels, hips, tailbone, ankles, shoulders, back, and the back of the head (Wysocki AB, 1995). Generally, pressure ulcers occur when a person is in a sitting or lying position for too long without shifting his or her weight. Thus, anyone confined to a chair or bed is at high risk (Cannon

& Cannon, 2004).

Pressure ulcers occur across the spectrum of health care settings world wide. A national survey in the United States reports a prevalence of 14.8 % across 365 acute hospitals (Amlung, Miller & Bosley, 2001). The highest incidence (the number of persons with new ulcers divided by the number of persons at risk) is actually in the hospital, while the highest prevalence (the number of persons with an ulcer divided by the number of persons at risk) is in long-term care facilities (Thomas D.R., 2001). From 57% to 60% of ulcers occur in hospitals (Guralink, Harris & White et al, 1988). The incidence in the hospitalized patients ranges from 3% to 30% (Clarke & Kadhom, 1988). Pressure ulcers occur during the stay of hospitalized patients, usually within the first two weeks (Guralink, Harris & White et al, 1988). In long term care facilities the prevalence ranges between 2.4% and 23% (Young, 1989). Fewer than 20% of pressure ulcers occur outside of institutions (Barbenel, Jordan & Nicol 1977). In home care patients, the prevalence ranges between 9% and 20% (Ferrell, Josephson, Norvid & Alcorn, 2000). Prevalence studies in Australian acute-care hospitals have found their prevalence to range from 4.5% to 27 % (Prentice& Stacey, 2001).

An important study by Woodbury & Houghton (2004) provides prevalence estimates for pressure ulcers in various Canadian healthcare settings of 15% to 30%, and an overall estimate of 26%. The data includes information from 18 acute care facilities involving 4,831 patients, 23 non-acute care facilities with 3,390 patients, 19 mixed care healthcare settings with 4,200 patients, and five community care agencies that surveyed 1,681 patients. These estimates seem to be higher than estimates from the US and the other European countries, perhaps because of the trend in the Canadian healthcare system to limit hospital admission and reduce length of stay; thereby, resulting in sicker patients within the system.

Pressure ulcers significantly reduce patient's quality of life and increase the cost of patient care, as well as the length of hospital stay (Cannon & Cannon, 2004). They constitute a significant financial burden on the health system. It has been estimated that the total cost of pressure ulcer care cost may fall between £1.4 billion and £2.1 billion a year in the United Kingdom (Bennet, Dealey & Posnett, 2004). The annual cost of treating pressure ulcers in the American healthcare system is estimated around $US 3.6 billion (Beckrich & Aronovitch, 1999). New data shows that this treatment cost has reached the level of US $ 7 billion per year (Autex 2004).

In 1987, Bergstrom and Braden developed the Braden scale for assessing pressure ulcers. The Braden Scale (Bergstrom & Braden 1987) is composed of 6 subscales: sensory perception, skin moisture, activity, mobility, nutrition, and friction and shear. Some other important scales to assess pressure ulcer status and healing are the Pressure Sore Status Tool, the Sessing Scale and the Sussman Tool (Morison 2001).

Despite all the different scales for assessing pressure ulcers, there are some common factors that are pressure, shear, friction and excessive moisture/liquid. Many researchers have conducted studies to determine the different reasons for ulcer formation, but unfortunately the role of textile materials has been understudied. Shear, friction and moisture are directly related to the characteristics of textile materials, while pressure plays a critical role in governing frictional actions on human skin once pressure and body movement are involved. The human body is in direct contact with fabrics or textile materials most of the time. If these factors are among the key players, then there is a dire need to study their effect on the patient's body.

1.2 Objectives

The principal objective of this study was to estimate the impact of textile products on the prevalence or incidence of skin lesions and pressure ulcers.

This study was conducted with the collaboration of the Riverview Health Centre, Winnipeg. This is a 388 bed hospital and with facilities for patients who need rehabilitation and long term care of particular interest were patients with complaints regarding several textile products potentially leading to skin lesions and ulceration. These products included nylon slings for patients/resident lifts, incontinent pads and hip protectors.

This study was a preliminary investigation of the physical and physiological interactions between fabric and skin, as well as their impact on the prevalence/incidence of skin lesions and pressure ulcers.

Skin/fabric interactions studied included pressure, friction, skin hydration and fabric moisture transport properties. These are factors often overlooked in previous research. The key focus of the study was to examine the moisture transportation properties and frictional properties of textiles and to find their impact on the formation and prevention of skin lesions and pressure ulcers.

This study was under taken to provide the groundwork for further studies in the quantification of skin/fabric interactions (frictional force and pressure distribution), and for the design and development of fabrics with optimum frictional and moisture transport properties that would prevent and relieve the formation of skin lesions and pressure ulcers.

Chapter 2: Literature Review

This literature review addresses the skin structure, the patients at risk of pressure ulcers, the different stages of pressure ulcer formation, main factors of forming pressure ulcers, and the impact of textile materials in the formation and prevention of pressure ulcers.

2.1 The Human Skin

Parakkal and Montagana (1974) provide detailed explanations of skin structure and function. According to them the skin consists of three layers:

2.1.1 Epidermis

The epidermis is the top most layer of the skin. It is the first barrier against external environment. It consists of three types of cells: keratinocytes, melanocytes and langerhans cells. Predominant types of cells in the epidermis are keratinocytes which are made of keratin protein. The uppermost layer of the epidermis is called the stratum corneum. This is the skin region directly contacted by fabrics. It is composed of several layers of dead keratinized cells generated by the underlying living dermis. The stratum corneum serves as the principal environmental barrier for the body by controlling the passage of water and governing the percutaneous absorption of environmental chemicals. It is relatively dry. 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. It loses water to the environment by evaporation.

2.1.2 Dermis

Beneath the epidermis is the dermis. It is the middle layer of the skin located between the epidermis and subcutaneous. It is the thickest of the skin layers and compromises a tight, sturdy mesh of collagen and elastin fibers. The dermis contains blood capillaries and vessels. 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 (Hatch & Markee et al., 1990). The amount of heat that can be dissipated from the body core is determined by the rate of blood flow to the skin. Successful healing of the skin, whether to a burn or minor abrasion, depends on an adequate supply of blood to the microcirculatory capillary vessels. The dermis also contains numerous nerve endings and receptors.

2.1.3 Subcutaneous

The subcutaneous is the innermost layer of the skin located under the dermis and consisting mainly of fat. The predominant types of cells in the subcutaneous layer are fat cells. Subcutaneous fat acts as a shock absorber and heat insulator, protecting underlying tissues from cold and mechanical trauma.

2.2 Skin Ulceration

Pressure ulcers are very common in the elderly, the very ill, patients who are neurologically compromised, and in people with conditions that are associated with immobility (Rachael F, 2005). According to a study (Thomas D.R., 2001), incontinence and decreased sensory perception (due to a stroke, for example) also increase the likelihood of developing bedsores. The constant pressure against the skin squeezes the blood vessels that supply nutrients and oxygen to the skin and nearby tissue, causing a decreased blood supply to the area. Subsequently, the skin can no longer survive and dies. Left untreated, nearby tissue begins to die, eventually resulting in an ulcer that reaches the bone, leaving an open cavity with resulting secondary infections that can cause death.

Stages of Pressure Ulcers Formation

National Pressure Ulcer Advisory Panel (NPUAP) has developed a system for evaluating pressure ulcers that spans from Stage I (earliest signs) to Stage IV (most advanced):

- **Stage I:** A reddened area on the skin that when pressed is "non-blanch able" (does not turn white). This indicates that a pressure ulcer is starting to develop.
- **Stage II:** The skin blisters or forms an open sore. The area around the sore may be red and irritated.
- **Stage III:** The skin breakdown now looks like a crater, where there is damage to the tissue below the skin.
- **Stage IV:** The pressure ulcer has become so deep that there is damage to the muscle and bone, and sometimes tendons and joints.

In a previous classification system there used to be a stage V. But this is not now used.

Of the four stages, Stage 1 ulcers are most common, accounting for 47 % of pressure ulcers. Stage 2 ulcers are a close second at 33 %. Stage 3 and 4 ulcers make up the 20 % difference (Meehan, 1994).

2.3 Major causes of pressure ulcers

It is already reported that pressure, shear and friction and excessive moisture are the key players in causing pressure ulcers (Morison 2001). These factors are largely dependant on each other. For example, the shear and friction forces between the skin and fabrics are functions of the pressure acting upon the skin.

2.3.1 Pressure

According to Vanderwee et al (2005), a major cause of pressure ulcers is pressure, or force per unit area, applied to susceptible tissues. Pressure is concentrated wherever weight bearing points come in contact with surfaces. But this root cause is not completely responsible to forming pressure ulcers. According to Defloor (1999) the compressive and shearing forces above a certain threshold and lasting for a certain time eventually cause damage to the tissues. The intermediate variable that determines how great these forces must be in order to cause damage , is called tissue tolerance. Tissue tolerance can be divided into two components. One is the tolerance to pressure and the other one is tolerance to changes in tissue oxygen concentration. Compressive forces refer to sustained pressure on a local point, for example, compression of the soft tissues between the bony prominences and the underlying surface.

Two studies by Kosiac (1961) and Dinsdale (1974) demonstrated experimentally that a high constant pressure of 70 mm/Hg applied for 2 hours produces irreversible cellular damage as compared to the capillary closing pressure of 32 mm/Hg.

One of the frequently used methods for reducing pressure is to turn and position the patient frequently. A 2-hour turning schedule for spinal injury patients was deduced empirically in 1946 (Kenedi, 1976). However, turning the patient to relieve pressure is a very costly nursing procedure.

Because of the limitations and cost of turning patients frequently, a number of devices have been developed for preventing pressure injury. Devices can be classified as pressure-relieving or pressure reducing. Most devices are pressure reducing. Some examples of these devices are foam mattresses, and devices filled with water, gel, or air.

Another interesting example is the Australian medical sheepskin (Jolley et al, 2004). This is specifically designed to reduce pressure, minimize shear and friction and absorb moisture. This has a denser and higher wool pile and can withstand multiple washes at 80° C.

The results of the study by Jolley et al (2004) suggested that an Australian medical sheepskin as a mattress overlay reduces the incidence of stage 1 or 2 pressure ulcers by 58% (1.6 compared with 3.7 pressure ulcers per 100 bed days) compared to standard nursing care among general hospital inpatients at low to moderate risk of developing a pressure ulcer.

In a similar study Marchand & Lidowski (1993) explored the use of genuine sheepskin for pressure ulcer prevention and treatment. For this purpose they compared the use of genuine merino sheepskin with synthetic sheepskin in two long term care institutions. The results of their study show that genuine merino sheepskin is more effective in the prevention and treatment of ulcers than artificial sheepskin. This is believed to be due to the properties of genuine sheepskin, such as the natural oils that create a silk like surface and reduce friction. Genuine sheepskin also assists in maintaining proper hydration of the epidermis as wool products absorb moisture.

Although some dynamic air mattresses and floatation systems can reduce pressure, all the benefit is lost if the head of the bed is elevated to 30 degrees (Hofman A, 1994). The only devices that consistently relieve pressure are low air-loss air-fluidized beds. Air-fluidized beds have been shown to reduce the development of pressure ulcers in hospitalized intensive care unit patients. When 98 patients were randomly assigned to an air-fluidized bed or a conventional mattress, significantly fewer patients developed pressure ulcers on the air fluidized beds (Pase MN, 1994).

In other studies, the impact of different pads and alternating pressure air mattresses has been studied for the prevention of pressure ulcers. Fader, Bain and Conttenden's (Mar/2004) study demonstrated that absorbent pads have a substantial adverse effect on the pressure distribution properties of mattresses. Pad folds appear to contribute to this effect, and pad smoothing reduced interface pressures slightly but significantly. Vanderwee K., Grypdonck M., and Defloor T (2005) studied the effectiveness of an alternating pressure mattress for the prevention of pressure ulcers. However their study concluded that patients nursed on an alternating pressure air mattress seemed to develop more severe pressure ulcers.

By taking a view of all these studies, a preventive device should be selected on the basis of cost, which varies considerably, and ease of use.

Although fabrics (clothing & bedding) alone cannot do much to reduce the pressure experienced by patients, they play a critical role in governing frictional actions on human skin once pressure and body motion are involved. And the combination of pressure & friction has been reported to be detrimental and deleterious to the skin and underlying tissues (Dinsdale, 1974).

The next section therefore will be dedicated to a discussion of the role friction/shear plays in the formation of pressure ulcers.

2.3.2 Shear & Friction

Shearing forces occur when two opposing surfaces slide over each other in opposite directions while friction occurs when two surfaces rub against each other (Barratt E., 1990).

According to Maklebust & Sieggreen (2001), **shear** is a mechanical force that is parallel rather than perpendicular to an area. It mainly affects the deep tissues. Shear is increased by elevating the head of the patient lying on a bed and as a result pressure increases on deep tissues. Body weight pulls the deep tissues attached to the bone in one direction while the surface of skin or tissue sticks to the sheets and remains stationary. The body skeleton actually slides downward inside the skin. The mechanical forces can obstruct or tear and stretch blood vessels. Shear is greatest when a patient is dragged along the surface of the sheets during repositioning. Minimizing shearing forces involves raising the head of the bed to no more than a 30 degree angle, except for short periods while the patient is eating or if medically contraindicated.

The presence of shearing forces decreases the time that tissue can remain under pressure before destruction occurs.

Maklebust & Sieggreen (2001) also explained **friction** as a force of two surfaces moving across one another causes friction and may create a wound that resembles an abrasion. Friction is a common cause of skin damage in patients who are unable to reposition themselves. Pulling a patient across the bed linen may rub away the protective outer layer of skin. This mechanical erosion of surface tissue increases the potential for deeper tissue damage because friction is the precursor of shear. Patients who have uncontrollable movements, patients who wear braces or appliances that rub against the skin and the elderly are at high risk for tissue damage by friction.

Friction clearly increases the susceptibility of the skin to pressure ulceration. Dinsdale (1974) in a study found that friction initially removes the stratum corneum and mechanically separates the epidermis above the basal cells. When pressure alone was applied, no pathological changes occur for pressures below 150 mm/Hg. Pressure alone requires a level of 290 mm/Hg to produce ulceration, whereas pressure with friction causes ulcers at 45 mm/Hg.

The friction of the human body on textiles, generally connected with irritation of the epidermis by the rough woven fabric structure causes the skin damage (beginning of pressure ulcers), or worsening those which already exist. In order to minimize the results of such skin damage as abrasions, chafes and red marks, the bed sheet fabrics used in hospitals should have proper biophysical properties. Important parameters of this type of textiles which can reduce the probability of skin abrasions and thus of pressure ulcers are low friction and shear coefficients (Pryczynska E., 2000).

Another study by Pryczynska E. et al (2003) revealed that the blended bed sheet fabrics made of cotton and polypropylene fibers with biophysical properties prove very effective in the prevention of pressure ulcers and bed sores. One of the important features of these sheet fabrics is their low coefficient of friction.

Syncerski & Frontczak-Wasiak (2004) studied the design and manufacture of a double-layer woven fabric with different friction coefficients on the face and back sides of the fabric. In addition the friction coefficient differed depending on the direction of the fabric. Cotton and viscose rayon yarns have been used as raw materials for the production of the woven fabrics, taking into account the future use of such fabrics in sheets to prevent pressure ulcers and bedsores. They found significant differences in friction coefficients between the yarn directions on both sides of the woven sheet fabric. The results of this study show that the materials which have a high coefficient of friction seem more abrasive. However, the efficiency of the sheets in controlling pressure ulcers has not been reported.

2.3.3 Excessive moisture/Liquid

The skin health and thermo physiological comfort of people are affected by the wetness of their skin. When skin wetness increases, the skin becomes more susceptible to abrasive damage, more readily absorbs chemicals, and is more prone to microbial growth (Zimmerer, Lawson & Calvert 1986).

Different textile products used by the wearers in hot, humid, indoor environments have a substantial potential to change the body's ability to achieve a state of thermophysiological and sensorial comfort. General feelings of thermal and wetness discomfort are caused by the improper movement of heat and moisture through a fabric. Under humid wearing conditions sensations such as prickliness, roughness, and scratchiness are increased (Li.Y 2001). Therefore, it is really necessary to maintain the temperature and moisture evaporation in the micro-climate between the skin and adjacent fabrics to attain more comfort.

Hatch et.al. (1987), studied the change in the wetness state of the skin due to wearing of apparel fabrics by sedentary and exercising subjects. In this study triacetate and polyester woven dress-weight fabrics are placed on a sedentary subject's forearms with and without coverings of occlusive plastic film. A focused microwave probe was used to assess the stratum corneum water content, and an evaporimeter measured the rate of water evaporation before and after removal of the fabric patches. Placement of either triacetate or polyester on the forearm without a covering of film did not cause detectable changes in water content or evaporation measured immediately after fabric removal, even when the fabric had been in contact with the skin for 90 minutes. Water content and evaporation increased as the fabric/film remained on the forearm for longer periods. Stratum corneum water content was generally greater for polyester/film-covered forearm sites than triacetate/film covered sites; but there was not a significant difference due to fabric type. Forearm water evaporation after fabric removal was also greater for polyester/film sites than for triacetate/film sites. This difference was also statistically significant. Occluded fabric placed on the skin influenced the stratum corneum water content and rate of water evaporation.

Hatch et.al. (1990), measured the heat and moisture transfer through a specially selected set of jersey knit textile fabrics (100% cotton, 100% 1.5 denier polyester, 100% 3.5 denier polyester). The results of this study show that there were only small differences in thermo-physiological comfort of the three experimental knit fabrics when worn under non-sweating conditions (cool to warm temperatures and low activity level). These experimental fabrics were found to be similar in geometric and volumetric structure. They were also similar in water vapor, air permeability as well as energy dissipation rates and in comfort limits.

On the other hand, liquid water transport differed significantly between the experimental fabrics. The knit made with hydrophilic cotton fibers exhibited a grater ability than the polyester knits to transport water by capillary mechanisms. The researchers predicted that the comfort of the three fabrics would be different when the fabrics were worn under conditions in which they become wet with sweat. Not only should subjects perceive a difference in comfort, but the rate of hydration of the skin under the fabrics was also being expected to vary.

Hatch et al (1990), also studied the stratum corneum water content, rate of water evaporation from the skin surface, capillary blood flow, and skin temperature under three different garments worn by ten female subjects exercising and resting in a hot, humid environment (29.4° C, 75% RH). Single knit fabrics made from 100% 1.5 denier polyester, 100% 3.5 denier polyester, or 100% cotton were made into long sleeve T-shirts and pants. The results of this study show that there were no significant differences between the three experimental fabrics in terms of alteration in capillary blood flow, stratum corneum water content, skin evaporative water loss, or skin temperature when the fabrics were worn by exercising subjects in a hot, humid environment.

Later Hatch et al (1992), then examined the effect of fiber type and fabric moisture content on stratum corneum hydration. It was generally observed that the fabrics placed over the human skin may change the hydration level of the stratum corneum. It was an important phenomenon because an increase in normal levels of stratum corneum hydration can cause potential health problems. For this purpose three similarly constructed knit fabrics, six fabric type/moisture content combinations were selected for the tests. Using an occluded plastic dome, fabric samples were placed on both normal and hydrated volar forearm skin of the subjects for a specified period, and then removed. Two minutes after removal, evaporative water loss and skin temperature were measured. The design of the study was a randomized complete block with all possible treatment combinations applied to each subject. The result showed that in general, evaporative water loss rates increase as the moisture content of the fabric increases. The effect of moisture on fibers in a fabric changes its flexural rigidity and subsequent collapse of fabric onto the skin surface and differences in the fibers' ability to absorb moisture therefore appear to influence evaporative water loss rates.

A further study of Hatch et a, (1997), examined the relationship between fabric moisture content and the level of stratum corneum hydration. Three fabric/moisture treatments were placed on the stratum corneum (3.5 denier polyester fabric with an initial moisture content of 35% and cotton fabrics with either 44% or 75% initial moisture content), then covered with an occlusive dome. Stratum corneum evaporative water loss was measured before treatment and after 30 and 60 minutes of contact. The amount of moisture in the fabric at the time of removal was calculated two different ways. Three analyses of variance were done using the evaporative water loss and two fabric final moisture content data sets. The rate of evaporative water loss was significantly higher after 30 minutes of treatment contact with stratum corneum than after 60 minutes of contact. The amount of moisture in the fabrics was significantly lower after 60 minutes than at 30 minutes. This study showed that as the fabric moisture content decreases, so too does the stratum corneum hydration.

Excessive moisture/liquid within the skin/fabric microclimate leads to perceived discomfort. And if it is combined with pressure and/or friction and shear, it may cause even more serious problems.

The study of Maklebust & Sieggreen (2001) revealed the effect of excessive moisture on the skin. Their study showed that wet or moist skin becomes ulcerated five times more quickly than dry skin. Constant exposure to wetness can waterlog or macerate the skin. Maceration becomes a contributing factor in causing pressure ulcers when excessive moisture softens the connective tissue. Macerated epidermis is easily eroded. Eventually, degenerative changes take place, and the tissue sloughs. In this way the adherence of wet skin surfaces to bed linen increases the risk of friction as the patient is moved across the surface of the bed linen. Excessive moisture may be the result of perspiration, wound drainage, soaking during bathing, and fecal or urinary incontinence.

However, there has been further debate about the role of incontinence/moisture in pressure ulcer development and whether it is a primary causative factor, a symptom of the patients' illness or whether it enhances local friction and shearing forces (Berlowitz & Wilking 1989, Bliss 1993). The study by Bliss (1993) also suggested that incontinence/moisture is not a primary factor but a symptom or indicator of poor physical condition, particularly in elderly populations. It is really important to maintain a proper microclimate between the patient's body and the textile products for the prevention of pressure ulcers and other skin diseases.

On the whole, the role that textiles play in the formation and prevention of skin lesions and ulcerations has not been studied at any great depth. One of the causes may be the lack of communication between researchers in the area of textiles (materials) and medicine (dermatology). The fact remains, textiles, such as clothing and bedding, have a considerable influence on factors such as pressure, shear/friction and skin hydration, which contribute to skin ulceration. Consequently, greater research efforts are necessary to gain a better understanding and attain more efficient methods to battle the problem of pressure ulceration.

Chapter 3: Experimental Methods

The present research is a preliminary study on skin/fabric interactions, and their impact on prevalence/incidence of bedsores. The roles of various measurable parameters in the formation and prevention of bedsores are examined. These parameters include the physical status of patients and the specifications of the textile products that have been reported to cause skin problems or injuries. This study will provide a foundation for further design and development of textile products for healthcare with desirable frictional and moisture transport properties to prevent/ relieve bedsores and provide optimum comfort for patients. Hopefully, the potential benefits will enhance the quality of life for patients and reduce the costs of both treatment and care.

3.1 Prevalence Survey Study

The first step of this study was to participate in the Pressure Ulcer Prevalence survey organized and conducted by the staff of Riverview Health Centre (RHC), Winnipeg. This facility conducts this kind of survey twice a year.

We joined the survey which was conducted on November, 2006. The main purpose of joining this practice was to collect information about the long term residents who were most vulnerable to pressure ulcers. The study involved volunteers from the Riverview Health Center (RHC), residents in personal care units, and the care-giving staff members (health care aides and registered nurses).

In the Prevalence/Incidence Survey, the following data were collected:

i). Incidence of pressure ulcers, their locations and classification.

ii). Physical status of residents (weight, mobility, gender, age, incontinence)

iii). Textile products used by residents, frequency and length of time for using such textile products

The data collection process was undertaken as part of pressure ulcer prevalence monitoring which is routinely performed at RHC. Information about pressure ulcers (i above) was obtained from pressure ulcer prevalence monitoring. Information about the physical status of participating residents (ii above) was obtained by reviewing their charts. Also the care giving staff members were interviewed about the textile products that were used (item iii above).

3.1.1 Sample Recruitment

A convenience sample for the study was recruited from among the 226 residents in the RHC personal care units. Invitations for participation and consent forms were send out to appropriate residents based on the following exclusion criteria:

i) A record of using medicines that could seriously affect the state of the skin e.g. (corticosteroids)

ii) Agitated or disruptive behaviors by the resident

iii) The public trustee being identified as the legal designate.

Only when the signed consent forms were returned, we did start the data collection process.

3.1.2 Data Collection

Data were obtained on Form I (see Appendix A) from three sources in this study; i) the resident's medical record, ii) RHC pressure ulcer prevalence monitoring, iii) and interviews with the residents' care giving staff:

i) Medical record. The following data were obtained from the chart -- Physical status of the resident, including weight, mobility, gender, age, incontinence (Appended Form I, Part A).

ii) RHC pressure ulcer prevalence monitoring. The following data were obtained from routine RHC pressure ulcer prevalence monitoring: incidence of pressure ulcers, their locations and stage (Form I, Part B).

iii) Interviews with the care-giving staff. An in-person interview was held with each participating resident's care-giving staff member to obtain the following information: textile products use by residents (clothing items worn next to the skin); textile products provided by the Riverview Health Center in special cases or treatments (lifting devices, hip protectors, incontinent products, etc.); frequency and length of time for using a textile product (Form I, Part C). During the interview, the researcher asked to take a look at the labels of the textile products for information about fiber content.

We kept confidential the identities of the participating RHC residents and healthcare staff. Only data without any identifying information were removed from Riverview Health Center. Therefore, there was no identifying information on the data collection sheet (Form I). However, recorded data were coded to keep track of subjects with multiple entries. The coding sheet was kept in a secure locked location at locked at RHC and will be destroyed by the end of the project.

3.2 Materials

Textile materials in this study were identified after analyzing the survey data. However, the following tests were performed to determine the characteristics of those materials:

1- Fabric weight: (ASTM D 3776-1996. Standard test method for measuring fabric weight).

2- Fabric Count: (ASTM D 3775-2002. Standard test method for measuring fabric count in woven fabrics).

3- Fabric Thickness: (ASTM D 1777-1996. Standard test method for thickness of textile materials).

Laundering procedures were performed according to the AATCC 135 – 2004 Standard test method (Dimensional changes of fabrics after home laundering).

3.3 Moisture Transportation

The most important evaluation in this study was the measurement of diffusion and transportation of moisture through textile materials and fabrics. For this purpose Type 684 Automated Water Vapour Diffusion Apparatus was employed. This apparatus was designed and built by S.E.A. Engineering Company and was used to measure the rate at which water vapor diffuses through fabrics. The apparatus uses a unique combination cell design which is described in the moisture diffusion test method specified in Canadian Standard CAN/CGSB – 4.2 No. 49-99 and in the Van Beest and Wittgen (VBW) method.

3.3.1 Description of the Apparatus's system

Basically the system of Automated Water Vapour Diffusion Apparatus (S.E.A. 2006) consists of water vapour diffusion cells mounted on laboratory balances. the water and dry air supply systems feeding each cell and the over all control system are shown in Figure 3.1.

The water supply system consists of syringe reservoirs, stopcocks and associated tubing and connecters. Each cell is supplied with an independent supply of water. The water supply for each cell is held in the syringe reservoir filled with distilled water. The water is fed from the syringe reservoir through a stopcock and plastic tubing to the cell.

The dry air supply system consists of an inline regulator, flow meters, "Drierite" drying columns and associated tubing and connectors that produce a constant flow of dry air to the moisture sink membrane of each cell. Laboratory air (at up to 300 psig) is fed to an in-line regulator mounted on the work station. Air from the outlet of this regulator is fed (at up to 50 psig) to the inlet of each of three flow meters. Air is metered by a needle valve in each flow meter inlet. This allows for independent adjustment of the flow to each cell. Each flow meter outlet feeds the air flow to two driers connected in series where the air stream is dried before being fed to the inlet of each cell.

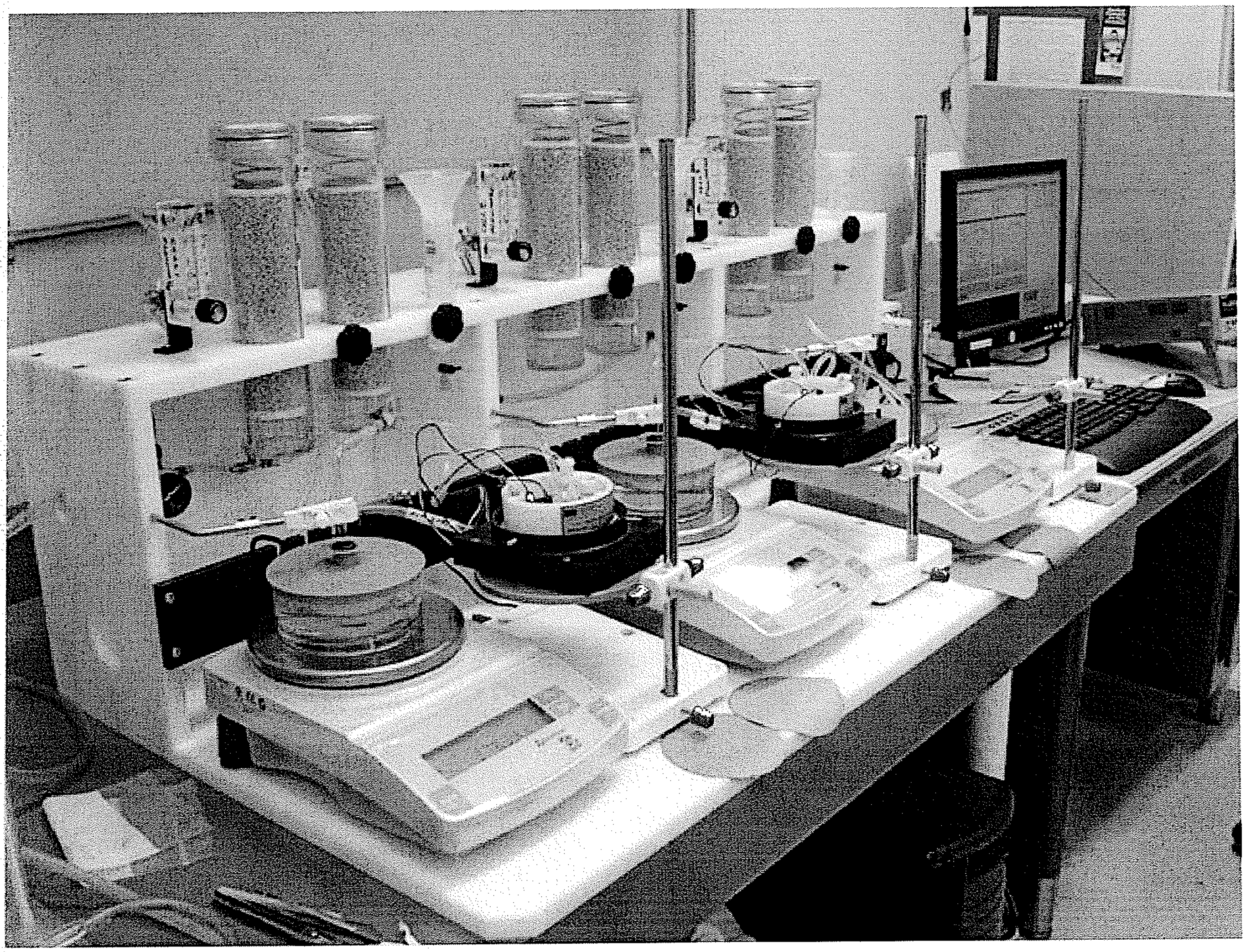


Figure 3.1: AWVD Apparatus

In the dry air supply system, air enters the system at the inlet in-line regulator. It leaves the regulator and enters a tubing manifold made of pvc/polyurethane tubing rated to 60 psig. This manifold feeds the air to the inlet needle valve of the flow meters. Low pressure inter-connecting tubing takes the air to the lower inlet of the left drying column of the pair of drying columns associated with each cell. From the outlet at the top of the left drying column, the interconnecting tubing takes the air to the lower inlet of the right drying column. From the upper outlet of the right drying column, the interconnecting tubing takes the now completely dry air into the inlet of the water vapour diffusion cell.

The desiccant dryers are mounted in the shelf of the workstation with an adjustable clamping feature that allows them to be readily removed for changing and recharging the drying agent.

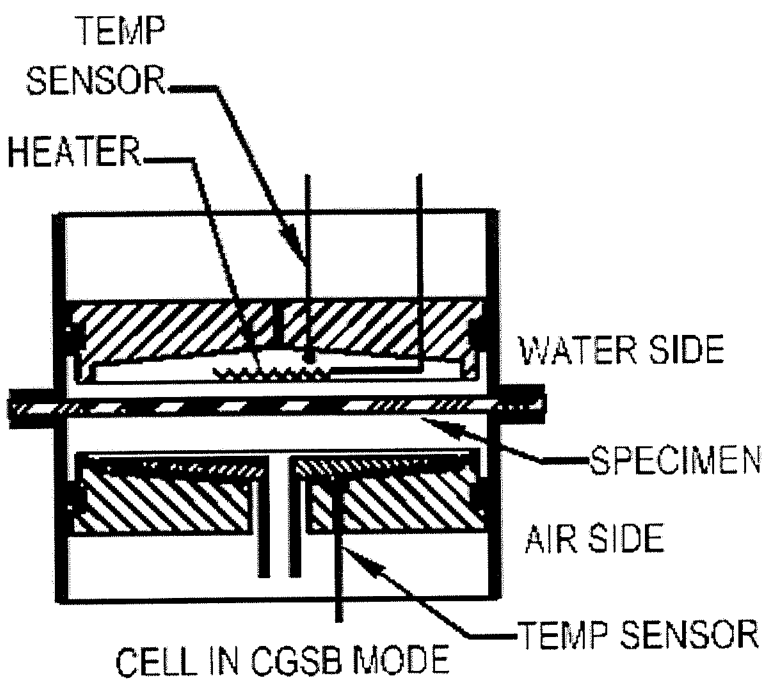
The control system consists of a data acquisition system mounted on a base, a computer, interface boards, power supplies, software and a power supply/connector/wiring harness assembly. A bench top work-station style framework supports and holds the components together.

3.3.2 Description of the Diffusion Cell's system

The main component of a water vapour diffusion apparatus (WVDA) is a cell which sets up a moisture gradient across a test specimen by maintaining 100% moisture vapour on one side of it and a moisture free sink on the other side as shown in Figure 3.2. The moisture source is water held behind a membrane and the sink is dry air behind another membrane.

Each cell contains a specimen chamber, a moisture source and a moisture free sink membrane. The cell consists of a water-side half-cell and an air-side half cell. The water side half-cell consists of water, a membrane pad made of 50/50 polyester/viscose rayon, and a second membrane made of Teflon film. The air-side half-cell consists of an air chamber base and cover, a membrane protection ring, a membrane made of Teflon, a gasket, support screen and thumbscrew for tightening. These two half cells sandwich the specimen between them. Air-side spacers and water side spacers are installed as required by the test protocol. When necessary, for example during filling, the two half-cells are locked together by thumb screws.

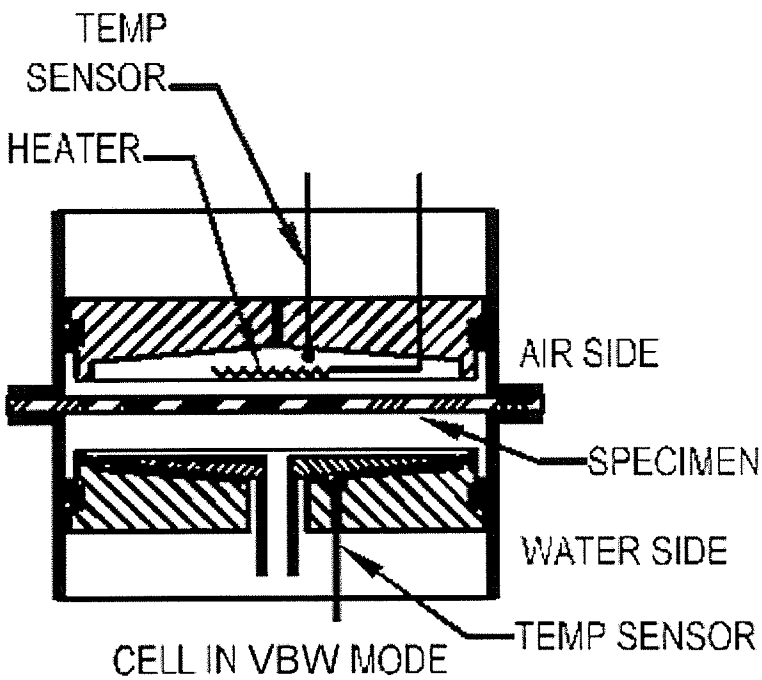
When set up in the CGSB mode, the cell can be used for making absolute measurements of the water vapour diffusion on a wide range of textile materials according to the CGSB standard, including those that have micro porous or hydrophilic laminations or coatings. In the CGSB mode, the wet membrane is above the test specimen and dry membrane is below the specimen, as shown in Figure 3.2(a).



http://www.designeng.com/WVDA_MODEL_643_1.htm

Figure 3.2 (a) A CGSB cell

When set up in the Van Beest and Wittgen (VBW) water vapour diffusion mode, the cell can be used for making absolute measurements on hydrophilic and non-hydrophilic fabrics. In this VBW mode, the wet membrane is below the test specimen and dry membrane is above the specimen, as shown in Figure 3.2(b).



http://www.designeng.com/WVDA_MODEL_643_1.htm

Figure 3.2 (b) A VBW cell

3.3.3 Experiment Methods

3.3.3.1 Test Method CAN/CGSB – 4.2 No. 49-99

This method is intended for use in determining the resistance of textile materials to water vapour diffusion. In this method, the test specimen is placed approximately at an equal distance between the base (dry airflow) and the cylinder (water cell). An Automated Water Vapour Diffusion Apparatus (AWVDA) is used to carry out this test.

The rate of diffusion of water vapour through the sandwich, which consists of two layers of micro-porous polytetrafluroethylene (PTFE) film, is calculated from the loss in mass of the water from the dish as a function of time. The water vapour resistance of the sandwich is then calculated. The resistance of the specimen is determined from the difference in the value for the sandwich to that obtained for the two films without the specimen in place.

3.3.3.1.1 Sample Preparation

At least four circular test specimens, with a diameter of 4.25 inches (10.795 cm), were cut from each sample in such a way that i) no two specimens contained the same warp or weft yarns (in case of woven materials), and ii) no specimen was taken from creased or damaged area of the sample.

3.3.3.1.2 Conditions of Testing

All specimen samples were conditioned in accordance with CAN/CGSB-No. 2. It means all specimens were conditioned in a standard testing atmosphere of 65 ± 2 percent relative humidity and 20 ± 2 degree Celsius for at least 24 hours prior to testing.

The room or cabinet where the test was performed had a controlled humidity and temperature (conditions as in CAN/CGSB-4.2 No.2) so as to minimize water temperature variations during the actual test.

3.3.3.1.3 Testing Procedure

The equipment components were arranged according to the CGSB-4.2 No.2 test method. Figure 3.2 shows the Vapour Moisture Diffusion Cell set up for the CGSB test.

Four specimens were prepared for this test. The water vapour diffusion cell was filled with distilled water. The air supply was turned on adjusting it to 4 $\pm$ 0.5 L/min. AWVDA application software was started and the dialog box for the CGSB test was checked. At first, in order to determine the resistance of the apparatus alone, a blank run was performed. To ensure the stability of the cell, it was recommended that these blank runs be performed before and after each sample test (set of four specimen determinations) and the values of the blank runs were averaged.

After the blank run, a test specimen was placed equidistance between the water-side half-cell (on top) and the air-side half-cell (on the bottom). In our test, both the air-side and water-side gap were set to be 0 (zero).

To start the test, “Start Test” was selected from the mouse right click menu. The system ran the required number of calculation intervals and displayed the calculated variable values for each interval and their average for the run in the test results table on the main screen. Generally one test run took 3 ¼ hours to complete.

For the next test, the system brought up a dialog box to set up the cell for the next run. This procedure was repeated for all 4 specimens. There were 6 intervals runs for each sample: two blank runs before and after the 4 runs with specimens.

When all runs were completed, the test stopped and the average values for all 6 runs were displayed for each test condition in the test results table on the main screen.

According to the CGSB test method, this consisted of a row showing the average results of the two blank runs and a second row showing the average values of the four specimen runs.

3.3.3.1.4 Water Vapour Calculation (CGSB Mode)

The following calculations were performed using this testing standard.

1- For each specimen tested, the slope was calculated using mass and time to determine the water vapour transmitted per second M_x (kg/s).

2- Average mass of water vapour transmitted per unit time M (kg/s) was determined from the four individual determinations of M_x (kg/s).

3- The vapour resistance (R) of a square meter area of the sandwich was calculated using the relation:

$$R = A\ \Delta P/M$$

Where:

A = the area of the specimen exposed to the water vapour, in square meters

ΔP = the difference in partial pressure of water vapour across the sandwich in Pa.

This is equal to the saturation vapour pressure.

M = the average mass of water vapour transmitted per unit time, in kg/s.

4- The vapour resistance of the empty cell R_B was calculated using the above equation and the data from the blank runs.

5- The vapour resistance of a unit area of the material R_{m} was calculated in $m^2Pa.s/kg$ using:

$$R_m = R - R_B$$

6- This value of R was converted to units of millimeters of equivalent still air, D_m by dividing by R_{air}. R_{air} is the resistance of one millimeter of still air at 20° C and one atmosphere of pressure.

$$D_m = R_m / R_{air}$$

Where: The resistance of one millimeter of still air at 20° C and one atmosphere of pressure is $5.4x10^6$ m^2 Pa s/kg. For other conditions of temperature and pressure it varies as:

$$R_{air} = 5.4x10^6 (Pa / 101.3) (Ta / 293)^{1.81}$$

Where: Pa = Atmospheric Pressure [kPa]

Ta = Air temperature [°K]

3.3.3.2 Van Beest and Wittgen (VBW) Test Method

This method is designed to determine the resistance of waterproof textile materials to water vapour diffusion under two different humidities. In the high humidity condition, one side of the specimen is wet. In the other condition, the mean difference in relative humidity between the two faces of the specimen is 50%. (However in this study this was 65 % because this %RH was already set in the conditioning room where these experiments were carried out). The water vapour diffusion resistance of some water proof coatings and films will be different under these two conditions. Either or both conditions may be specified for water proof materials. Ordinary materials can only be tested at the 65% relative humidity condition. An Automated Water Vapour Diffusion Apparatus is usually employed to carry out this test.

3.3.3.2.1 Sample Preparation

Four circular test specimens, with a diameter of 4.25 inches (10.795 cm), were cut from each sample in such a way that no two specimens contained the same warp or weft yarns (in case of woven materials), and no specimen was taken from a creased or damaged area of the sample.

3.3.3.2.2 Conditions of Testing

All specimen samples were conditioned in accordance with CAN/CGSB-No. 2 Method, (Conditioning textile materials for testing). It means all specimens were conditioned in a standard testing atmosphere of 65 ± 2 percent relative humidity and 20 ± 2 degree Celsius for at least 24 hours prior to testing.

The room or cabinet where the test was performed had a controlled humidity and temperature condition to minimize water temperature variations during the actual test.

3.3.3.1.3 Testing Procedure

The equipment components were arranged according to the VBW (Van Beest & Wittgen) test method, but the dry air chamber was not placed immediately on top of the test cell.

In this mode the cell can be set up in two alternative ways. One uses a PTFE membrane for the wet membrane and the other uses filter paper instead. In this test method the wet membrane's position is below the test specimen. In this project, filter paper was used as the wet membrane in the apparatus. The filter paper membrane allowed liquid water to contact the specimen directly as is the case in some real situations.

Four specimens were prepared for this test. The water vapour diffusion cell was filled with distilled water. The air supply was turned on and adjusted to 4 $\pm$ 0.5 L/min. The AWVDA application software was started and the dialog box for a VBW test was checked.

The test specimen was placed on the wet membrane and the air-side half-cell was then placed on top. In the present study, all VBW tests used a 1 cm air-side gap and a zero water-side gap to simulate the case in which fabric are in close contact with human skin and perspiration.

To start the test, "Start Test" was selected from the mouse right click menu. The system ran the required number of calculation intervals and displayed the calculated variable values for each interval and their average for the run in the test results table on the main screen. Generally one testing run took 3 ¼ hours to complete.

For the next test, the system brought up a dialog box to set up the cell for the next run. There were 6 runs for each sample; two blank runs, one before and one after the 4 runs for the specimens. When all 6 runs were completed, the test stopped and the average values for all runs under each test condition were displayed in the test results table on the main screen. For the VBW test, this consisted of a row showing the average values for the blank runs and a row showing the average values for the specimen runs.

3.3.3.1.4 Water Vapour Calculation (VBW Mode)

The following calculations were performed using this testing standard.

1- For each specimen tested, the volume of water in millimeters was plotted against time in seconds. The slope of the line was calculated, which corresponded to the volume of water vapour transmitted per second, V_x (ml/s).

2- The average volume of water vapour transmitted per second, V (ml/s) was determined from the four individual determinations, V_x (ml/s).

3- The vapour resistance (R) of a square meter area of the sandwich was calculated by using the relation:

$$R = A\,\Delta D / (V\,d) \qquad [s/m]$$

Where:

A = the area of the specimen exposed to water vapour, in square meters

ΔD = the difference in water vapour concentration across the sandwich (g/m^3), this is equal to the saturation water vapour density at the wet membrane.

V = the average volume of the water vapour transmitted per unit time, in ml/s.

d = the density of pure water

= 1 g/ml

4- The vapour resistance of the empty cell R_B was calculated using the above equation and the data obtained from the blank runs.

5- The vapour resistance of a unit area of the material R_m was calculated using:

$$R_m = R - R_B \quad (s/m)$$

6- This value of Rm was converted to units of millimeters of equivalent still air by multiplying by D_{air}, the diffusion coefficient of water vapour into air at the temperature and pressure of the test.

$$D_m = R_m \times D_{air}$$

Where: The diffusion coefficient of water vapour into air, D_{air}, is 25×10^{-6} m²/s at 20° C and 101.325 kPa. For other conditions of temperature and pressure it varies as:

$$D_{air} = (0.926 / Pa)\,[Ta^{2.5} / (Ta+245)] \times 10^{-6}$$

Where: Pa = Atmospheric Pressure [kPa]

Ta = Air temperature [°K]

3.4 Testing Frictional Properties of Textiles

For estimating the role of friction and shear factor, the properties of fabric hand and stiffness were measured experimentally.

In this study the Kawabata Evaluation System was used. The Kawabata system of instruments measures the sensory properties of textile fabrics and predicts the aesthetic qualities perceived by human touch.

The Kawabata Evaluation System (KES) includes five highly sensitive instruments that measure fabric bending, shearing, tensile and compressive stiffness, as well as the smoothness and frictional properties of a fabric surface. The specialized instruments are:

FB1	Tensile and Shearing
FB2	Bending
FB3	Compression
FB4	Surface friction and variation

The Kawabata Evaluation System (KES) is used to make objective measurements of hand properties. The KES instruments measure mechanical properties that correspond to the fundamental deformation of fabrics in hand manipulation.

3.4.1 Sample Preparation

A standard specimen size of 20 x 20 cm was used with three replications. All measurements were directional, except for compression, and were made in both the lengthwise and crosswise directions of the sample.

3.4.2 Conditions of Testing

All specimens were conditioned in a standard testing atmosphere of 65 ± 2 percent relative humidity and 20 ± 2 degree Celsius for at least 24 hours prior to testing.

3.4.3 Testing Procedures

This test system was not available in the textile testing laboratory of University of Manitoba. Therefore these tests were be performed in the textile testing laboratory of Groupe CTT Group, Saint Hyacinthe, QC, Canada.

The surface properties of friction (resistance/drag) and surface contour (roughness) were determined using the KES-FB4 Surface Tester. A tension load of 20 gram-force/cm was applied to the sample in the standard test and MIU & SMD values were measured.

Where;

MIU - coefficient of friction (0 to 1 value)

The coefficient of friction (μ) is a unit-less number. It is a ratio of the frictional force (F) divided by the normal force (N).

$$\mu = F / N$$

Higher MIU value corresponds to greater friction or resistance and drag.

SMD - geometric roughness (expressed in microns). A higher SMD value corresponds to a geometrically rougher surface.

3.5 Measuring Air-Permeability of Textiles

Another important evaluation in this study was to measure the air permeability of the textile materials or fabrics.

Air permeability is an important factor in the performance of textile materials. It can also be used to provide an indication of the porosity and/or breathability of weather-resistant and rainproof fabrics. Construction factors and finishing techniques can have an effect upon the air permeability by causing a change in the length of airflow paths through a fabric.

Fabrics with different surface textures on either side can have a different air permeability depending upon the direction of air flow. For a woven fabric, yarn twist is also important. As twist increases, the yarn diameter and the cover factor decrease with constant yarn spacing or frequency in the fabric (woven fabric count). This increases air permeability. However increasing yarn twist may also allow the more circular, denser yarns to pack more closely together in a tighter woven structure. This structure will have a lower yarn spacing or higher woven fabric count with reduced air permeability.

In this study an air permeability testing apparatus was used and testing was performed according to the test method specified in Canadian Standards CAN/CGSB – 4.2 No. 36-M89.

This method measures the air permeability in terms of the number of cubic centimeters of air passing through one square centimeter of fabric per second when the differential air pressure between opposite sides of the fabric is equal to 12.7 mm of water. It is applicable to all types of fabrics and to a variety of other permeable materials in sheet form.

3.5.1 Sample Preparation

The test specimen consisted of a full width sample of fabric of sufficient length to provide ten test areas across the sample at points chosen at random to represent the entire sample, excluding only the selvage. No two test areas contained the same warp or weft yarns nor did any test area include a portion of the fabric that had been sampled previously.

3.5.2 Conditions of Testing

All specimens were conditioned in a standard testing atmosphere of 65 ± 2 percent relative humidity and 20 ± 2 degree Celsius for at least 24 hours prior to testing.

3.5.3 Testing Procedures

This apparatus was capable of forcing air through a known area of fabric while also providing a means of adjusting and measuring both the flow of air through the test area and the pressure differential established between the opposite faces of the specimen.

A circle of fabric was clamped (circular test head had a test area of 5.93 square inches) in the testing device, taking care to smooth out any wrinkles or creases before clamping. The air pressure differential was adjusted to 12.7 mm water gauge pressure. This differential was measured by means of an inclined oil or water manometer with a slope of 1:10. The volume of air passing through the specimen was measured by means of a calibrated orifice. The pressure change at the orifice was observed with a suitable manometer.

Ten determinations were made across the sample at points chosen to represent the entire sample. The average value obtained from ten determinations was expressed as the air permeability of the sample in cubic centimeter per square centimeter per second ($cm^3/cm^2/sec$) at 12.7 mm water pressure.

3.6 Statistical Analysis

"Significance test for a difference in two proportions" (Swinscow & Campbell) was performed to do the statistical analysis of the survey data.

A $p<0.05$ level of significance was used throughout the statistical analysis.

Chapter 4: Results & Discussions

4.1 Results & Discussions of Survey Study:

4.1.1. Subject Recruitment

A convenience sample for the study was recruited from 170 residents in the Riverview Health Centre (RHC) personal care units.

The survey involved volunteers from among the RHC residents in the personal care units and staff members i.e. health care aides and registered nurses working at RHC. Patient care managers (PCM) at selected personal care units at RHC were sent an envelope containing the Data Collection Form (Appendix A), a cover letter that explained the purpose of study, consent forms, and a prepaid return envelop. The patient care managers were sent this mail in September 2006 to recruit subjects from the 52 potential participant residents of CD-2, CD-3 and CD-4 at RHC. The potential number of subjects was based on the following exclusion criteria which were used to exclude patients:

i) A record of using medicines that could seriously affect the condition of the skin (e.g. corticosteroids)

ii) Agitated or disruptive behaviors by the resident

iii) The public trustee was identified as the legal designate for the patient.

CD-1 did not participate in the study because the patient care manager went on sick leave.

Patient care managers of CD-2, CD-3 and CD-4 units decided that in the case of patients who were unable to give valid informed consent for reasons of age, disability, or other vulnerability, the consent form would be sent to their family members.

Follow up letters were sent again in November 2006 to increase the rate of responses.

Written consent from residents (or their family members) were received from each unit in the following numbers:

CD-2 = 2 (out of 6 potential participants) 33.3%

CD-3 = 8 (out of 18 potential participants) 44.4%

CD-4 = 12 (out of 27 potential participants) 44.4%

The entire response rate from these 3 personal care units was 43.13% (22 out of 51 potential participants).

A letter and a consent form were also sent to appropriate care giving staff members who were invited to participate in this study. When the written consent forms had been signed and received from the staff members the researcher scheduled a meeting with them in mid January 2007 in order to discuss the desired information listed in Form I, Part C (see Appendix A).

4.1.2 Survey Study

Each in-person interview with a participating resident's caregiver took 10 to 15 minutes to collect the information on Form I, Part C (see Appendix A). This information included: textile products used by residents (clothing items worn next to the skin); textile products provided by the RHC in special cases or for special treatments (lifting devices, hip protectors, incontinent products, etc.); frequency and length of time for using each particular textile product; and labels of the textile products providing information about fiber content.

Other information was obtained from the patient chart & file including their physical status such as weight, mobility, gender, age, and state of incontinence (Form I, Part A/see Appendix A). Information about pressure ulcer prevalence monitoring was obtained from Form I, Part B recorded for routine RHC pressure ulcer prevalence monitoring: Including the incidence of pressure ulcers, their location and classification. Table 4.1 was generated from the information from Form I. This table provides the information about gender, skin-problems, mobility, use of incontinence products, wheel chair seat covers, hip savers, and transfer lift devices for all 22 patients from CD-2, CD-3 & CD-4. This information is used to analyze and develop the correlation among significant factors of pressure ulcer formation. It can be seen from the table that patients were given an identity code number. No personal information was recorded for individual patients so as to respect their confidentiality and privacy.

"Significance test for a difference in two proportions" (Swinscow & Campbell) was performed to do the statistical analysis of the survey data.

It can be seen from Table 4.1 that two participants (9.09%) were identified with skin problems such as abrasions, rashes, and while three patients (13.63%) had bed sores or pressure ulcers at different stages.

Some of the possible factors that can affect the incidence of skin problems are discussed in the following section:

Gender

It can be seen from Table 4.1 that four males (18.2% of the participants) and 18 female patients which constitutes 81.8% of the participants participated in the survey. Two out of the four males are identified with skin problems, while only two out of 18 females were identified with skin problems. It seems that male participants in the study had a higher tendency to develop skin problems than female participants. However statistical analysis failed to establish a significant relationship between gender and the incidence of skin problems. The statistical analyses are as follows:

Table 4.1 (2006 Nov. surveys)

Identity code	Gender	Abrasions/ rashes/ lesions	Bedsores	Mobility			Incont. Briefs[2]	Cushion	Hip Saver (24h)	Transfer lift device
				Walking	Time spent on Wheelchair/bed	Mobile[1]				
CD2-01	F				24h		Y			Y
CD2-02	F			<2h	22h	Y	Y	Rolio cushion		
CD3-01	F			4-6 h	12h	Y	Y		Y	
CD3-02	F	Y			24h		Y	cushion		Y
CD3-03	F				24h		Y	gel cushion		Y
CD3-04	M				24h		Y	cushion		Y
CD3-05	M		Y		24h		Y			Y
CD3-06	F				24h		Y			Y
CD3-07	F		Y		24h		Y	air cushion, gel pad		Y
CD3-08	F			4~6h	18h	Y			Y	
CD4-01	F			<1h	23h	Y				
CD4-02	F			5~6 h	12h	Y				
CD4-03	F			8-10h	14-16h	Y	Y			
CD4-04	F				24h					Y
CD4-05	F			>10h	12h	Y				
CD4-06	F				24h		Y			Y
CD4-07	F			>10h	12h	Y	Y		Y	
CD4-08	M				24h		Y	gel cushion		Y
CD4-09	F			4~6h	18h	Y				
CD4-10	M	Y			24h		Y			Y
CD4-11	F				24h		Y			Y
CD4-12	F		Y		24h		Y			Y

[1] Mobile: Time spent on wheelchair/bed<24h/day; do not need lift to move around
[2] Incontinence Briefs: 4~6/day

Table: 4.1(a)

	With skin problems	Without skin problems
Male Patients	2	2
Female Patients	2	16
Total	4	18

From this table the data-information shows that

No. of males with & with out skin problems = 2+2 = 4

No. of females with & with out skin problems = 2+16 = 18

Total no. of people in the sample = 4+18 = 22

Mobile patients without skin problems = 9

Immobile patients with skin problems = 5

Immobile patients without skin problems = 8

Percentage of male patients = 4/22 = 18.18 %

Percentage of female patients = 18/22 = 81.82 %

Putting these values in the formula S.E (diff%) = $[p\ (100-p)/n1 + p\ (100-p)/n2]^{1/2}$,

The standard error of the difference between the percentages is calculated to be 25.01.

The difference between the percentage of male patients with and without skin problems was 38.9%. To find the probability attached to this difference, it is divided by its standard error:

$$z = 38.9/25.01 = 1.55$$

From the table in the appendix (Swinscow & Campbell), it has found out that the p value is 0.12 which is > 0.05. This shows that it is hard to establish a direct relationship between gender and incidence of skin problems.

Use of incontinence products

It can be seen from Table 4.1, that most of the patients were using incontinence products. The frequency of use of these briefs is 4-6 pads per day and no complaints or complications caused by incontinence were found. This reveals that the incontinence factor is well covered and cared by the care-givers at RHC so they cannot be considered a risk for patients. The statistical analysis from Table 4.1(b) is as follows:

Table: 4.1(b)

	With skin problems	Without skin problems
Patients using incontinent products	5	11
Patients not using incontinent products	0	6
Total	5	17

From this table the data shows that

No. of patients using incontinence products with & without skin problems = 5+11 = 16

No. of patients not using incontinence products with & without skin problems = 0+6 = 6

Total no. of people in the sample = 16+6 = 22

Percentage of patients using incontinence products = 16/22 = 72.72%

Percentage of patients not using incontinence products = 6/22 = 27.28 %

Putting these values in the formula S.E (diff%) = $[p\ (100\text{-}p)/n1 + p\ (100\text{-}p)/n2]^{1/2}$,

The standard error of the difference between the percentages is calculated as 25.01.

The difference between the percentage of patients using incontinence products with skin problems and without skin problems is 35.3%. To find the probability attached to this difference, the difference is divided by the standard error: $z = 35.3/25.01 = 1.4$

From Table A "Probabilities related to multiples of standard deviations for a normal distribution" (Swinscow & Campbell), it was found out that p value is 0.16 which is greater than 0.05. Therefore the statistical analysis failed to establish a significant relationship between using incontinence products and the incidence of skin problems.

Use of hip protection savers and mechanical lift devices

Three patients were found to use hip protection savers. A mechanical lift device was used to transfer the patients from their beds to wheel chairs or to bring them to a sitting position for their meals. The use of this device is not for a long duration and is very limited in time. It was identified that 13 patients were using this device. From the statistical analysis the p value calculated for this section lay at 0.80 which is greater than 0.05. This shows that there was no significant effect by the use of hip protection savers.

Mobility

As far as mobility is concerned, it is seen from Table 4.1 that the patients who can walk independently or with some help and are spending some time in walking are considered as mobile subjects. Their walking duration ranges from less than 1 hour to 10 hours every day.

On the basis of mobility it was identified that 9 patients out of the 22 were mobile which constituted 40.90% of the total participating population.

The use of a wheel chair among all residents was very common due to the physical status and old age of the patients. Six patients were identified as using wheel chairs for longer time periods when they were out of bed. But the duration of time spent in beds and wheel chairs differed from person to person. This time period ranges from 12 hours to 24 hours every day. It can also be seen from Table 4.1 that different kinds of seat covers have been used for these wheel chairs.

From Table 4.1 it can also be seen that the patients who were not very mobile spent most of their time either in their beds or in wheel chairs. In some cases it amounted to 24 hours a day. It is evident that all 5 patients suffering from skin problems were immobile and spending almost 24 hours in beds and wheel chairs. This observation helps to develop the direct relationship between immobility and the skin problems. It can be said that the main cause of developing pressure ulcers in these patients was immobility. In this situation the textile materials which had direct contact with the patients were bed spreads and wheel-chair seat covers. Other materials like incontinence pads, the nylon slings of mechanical lifts and hip protectors did not have a prominent impact on the patients and it is hard to correlate them with pressure ulcers.

The results from statistical analysis are presented in Table 4.1(c) is generated. In this table the all data is collected from table 4.1. This data shows that total population in the sample was 22 patients. These patients were separated into patients with mobility and without mobility. The mobile patients with and without skin problems were identified. Similarly immobile patients with and without skin problems were also identified.

Table: 4.1(c)

	With skin problems	Without skin problems
Patients with mobility	0	9
Patients without mobility	5	8
Total	5	17

From this table the data shows that

No. of patients with mobility = 9+0 = 9

No. of patients without mobility = 5+8 =13

No. of people in the sample = 9+13 = 22

Percentage of patients with mobility = 9/22 = 40.90 %

Percentage of patients without mobility =13/22 = 59.10 %

Putting these values in the formula S.E (diff%) = $[p(100-p)/n1 + p(100-p)/n2]^{1/2}$

S.E (diff%) = $(40.9x59.1/5 + 40.9x59.1/17)^{1/2}$

S.E (diff%) = the standard error of the difference between the percentages = 25.01

So the difference between the percentage of mobile patients with skin problems and without skin problems is 52.9%. To find the probability attached to this difference, the difference was divided by the standard error: z = 52.9/25.01 = 2.11.

From table A in the appendix (Swinscow & Campbell), it was found out that p lies at 0.03 which is less than 0.05. This value shows that immobility was the significant factor in causing skin problems.

This finding is also supported by the study of Margareta & Mitra et al. (2004) which stated that immobility is a risk factor of major importance for pressure ulcer development among adult hospitalized patients. The results of this study also indicate that the RAPS (Risk Assessment Pressure Sore) scale may be useful for prediction of pressure ulcer development in clinical practice.

Another study (Baumgarten & Margolis et al., 2006) showed that a small but significant proportion of elderly emergently admitted hospital patients acquired pressure ulcers soon after their admission. But this study suggests that new models of care may be required to ensure that preventive interventions are provided very early in the elderly person's hospital stay.

In addition, Allman & Goode et al., (1995) have suggested that nonblanchable erythema, lymphopenia, immobility, dry skin, and decreased body weight are independent and significant risk factors for pressure ulcers in hospitalized patients whose activity level is limited to a bed or chair.

From previous studies and from the present findings it is concluded that immobility is one of the most important host factors that contributes to pressure ulcer development.

In general, individuals that are bed or chair bound experience prolonged pressure and shear or friction that puts them at risk for developing a pressure ulcer. This occurs through:

- Skin rubbing against the bed sheets or chair
- Skin being pulled from repeated episodes of sliding down in the bed or chair
- Heels sliding against the bed linens
- Friction on the skin caused by repeated episodes of pulling up in the bed or chair

In other words it means that when patients are immobile, most of the time either they will be in their beds or in their wheel chairs. During their stay they will have direct contact with bed linens and wheel chair bed covers. So in this situation the materials which have a direct influence on causing skin problems are bed linens and wheel chair seat-covers.

On the basis of this statistical analysis, further experiments were done on the bed linens routinely used at RHC. These materials were tested to determine the moisture diffusion and water-vapour transportation properties by using an automated water vapour diffusion apparatus. The other important determinations were to measure the surface properties of friction (resistance/drag) and surface contour (roughness) by using a Kawabata KES-FB4 Surface Tester and to determine the air permeability of the fabrics using an air permeability testing apparatus.

4.2 Results and Discussion of Frictional Properties of Textiles

After the statistical analysis of the survey data, it was found that the most important textile material which had direct contact with the bodies of the immobile patients at RHC was bed linen. Therefore bed linen used routinely at RHC was tested and its frictional properties and surface roughness were measured by Kawabata Evaluation System. The RHC provided the bed sheet samples that were unused.

Table 4.2 (a) shows these characteristics

Table 4.2 (a)

Characteristic	Average	Standard Deviation
Fabric Weight	286.96 grams/meter^2	3.32
Warp Count	45 Tex	2.91
Weft Count	176 Tex	2.94
Warp/10 cm	136	3.39
Weft/10 cm	112	1.21
Fabric thickness	0.64 mm	0.03

For measuring the frictional properties of this bed sheet, the sample was divided into two groups. One was unused, and the other was after 10 washes. The washing was carried out by exposing the fabric to AATCC-135 Standard method (dimensional changes of fabrics after home laundering). Both groups of the bed sheet were then tested on the Kawabata KE-5 under dry (at standard condition) and at 65% wet condition. To achieve this wet pick up was brought to 65% of the original weight of tested sample. The tests were performed by Groupe CTT Group, Saint Hyacinthe, QC, Canada.

The results obtained are shown in Table 4.2 (b)

Table 4.2 (b)

Sample	Group	Condition	MIU (Avg.)	SMD (Avg.)
Length	Unused	Dry	0.233	1.047
Width	Unused	Dry	0.249	0.763
Length	Unused	At 65% wet	0.492	0.152
Width	Unused	At 65% wet	0.554	0.150
Length	After 10 washes	Dry	0.274	0.827
Width	After 10 washes	Dry	0.294	0.710
Length	After 10 washes	At 65% wet	0.495	0.658
Width	After 10 washes	At 65% wet	0.523	0.418

Here, MIU means the coefficient of friction and the value lies between 0 to 1. A higher MIU value corresponds to greater friction or resistance to drag. SMD means the geometric roughness and is expressed in microns. A higher SMD value corresponds to geometrically rougher surface.

These results show that in dry condition the MIU values of the unused bed sheet samples were significantly lower than when 65% wet. When the MIU values in the wet condition of the unused samples are compared with the MIU values under the dry condition it is observed that there was a 111.2% increase in the lengthwise direction and a 122.5% increase in the widthwise direction. This is a significant change.

Similarly for the washed samples, the MIU value under the dry condition was much lower than when 65% wet. The comparison of MIU values between the wet and dry conditions for the washed samples shows that there was an increase of 80.65% when wet in the lengthwise direction and 77.89% in the widthwise direction. These findings clearly indicate that as the wetness of the fabric increases, so the frictional resistance of the fabric also increases.

It has already been identified (Li.Y 2001) that as moisture content increases, the friction and displacement of skin increases, which triggers more sensory receptors in the skin. Therefore, a fabric that is perceived to be comfortable under low humidity conditions may be perceived to be uncomfortable under higher humidity or sweating conditions. These results showed that fabric wetness or excessive moisture in the fabric and its frictional properties have a direct relationship.

On the basis of these results it can be said that the presence of excessive moisture or water enhances frictional resistance of the bed sheet linen which could cause more chances of developing pressure ulcers in the patients.

These results also show that laundry cycles have an impact on the frictional properties of bed sheets but not at a significant level. When the MIU values of unused and washed samples are compared, it is observed that under dry conditions the washed samples had a higher value for the co-efficient of friction. In the lengthwise direction the increase for the washed sample was 17.6% more than for the unused sample. In the widthwise direction it was 18.0%.

However under wet conditions the difference between the MIU values of the unused and the washed samples was not significant. In the lengthwise direction the washed sample's MIU value was 0.6% more than for the unused sample. And in the widthwise direction, the MIU value for the washed sample decreased 5.5% compared to the unused sample. From these results it can be said that there was a little change in values of coefficient of friction after 10 laundry cycles.

Another important finding concerned the geometrical roughness of the surface of the bed sheet linens. Fabric roughness and scratchiness are important tactile sensations determining the comfort performance of a fabric worn next to the skin. The friction between skin and fabric is smaller with a fabric having a smoother surface than with a fabric having a rougher surface. But in this bed sheet linen case, it is seen from Table 4.2 (b) that in the dry condition for both unused and washed samples, the values of SMD were higher than the 65% wet samples. This difference is more significant in the unused state than for the washed samples.

The reason of this cause could be due to the presence of excessive amounts of water or moisture. Water tends to hold fiber ends to the fabric and make a smoother surface. Still this effect is far less significant than the increase of contact area between skin and fabric under wet conditions, which is usually perceived as a "sticky" feeling. As a result, the increase of wetness greatly increases the friction forces between fabric and skin, and may increase the risk of skin problems.

4.3 Results and Discussion of Moisture Vapour Diffusion & Air Permeability Results

An important experimental segment of this study was to conduct tests to determine the air permeability and the moisture diffusion for estimation of vapour moisture diffusion in the bed sheet linen (85%/cotton, 15%/polyester) used routinely at RHC. Three other textile samples were obtained from the Test Fabric Inc., which supplies standard testing fabrics with different fiber blend levels and specifications. These fabrics were 100% cotton, polyester-cotton (65 %/polyester, 35%/cotton) and 100% polyester. These three fabrics were selected due to the little size of the bed sheet samples. Generally bed sheet linens used in health care facilities are made of these materials or their blends. Therefore, the purpose of testing these three materials in addition to the bed sheet linen from RHC was to make a comparison between their air permeability and moisture vapour diffusion behaviors.

4.3.1 Air Permeability

Air permeability tests were conducted to determine the air permeability which is an indicator of the porosity of a fabric. Table 4.3 shows the air permeability test results for the RHC bed sheet fabric (85%/cotton, 15%/polyester) and other three fabrics, 100% cotton, polyester-cotton (65% /polyester, 35%/cotton), and 100% polyester. All these fabrics were tested according to the test method CAN/CGSB-4.2 No. 36-M89 to compare their air permeability and to calculate their porosity.

It has been stated (Collier & Epps 1999) that moisture and air movement through a fabric are sometimes considered together under the topic of fluid flow. Air flow is similar to diffusion of moisture vapour through a textile fabric. The air permeability of textile fabrics is the degree to which the material is penetrable by air. Air flow through a fabric occurs when the air pressure is different between the two sides of the fabric. Air permeability is the rate of air flow through the fabric when there is a different air pressure on either surface of the fabric. The air permeability test can therefore be used to provide an indication of the breath ability of textile fabrics.

Air permeability increases as fabric interstices increase in number and size. In other words, normally as fabric porosity increases, air permeability also increases. The porosity of a fabric is the total volume of void space within a specified volume of the fabric (Booth, 1961).

In this study, the RHC bed sheet linen fabric and the other three fabrics were all tested in the unused state, without any laundering process.

Table 4.3

Fabric Specifications	Bed sheet linen from RHC	Cotton	Polyester-Cotton	Polyester
Fiber Content	85% cotton, 15% polyester	100% cotton	65%polyester, 35% cotton	100% polyester
Warp Count (Tex)	45	36.3	11.8	30.9
Weft Count (Tex)	176	49.2	13.6	21.3
Warp/10 cm	136	430	380	260
Weft/10 cm	112	230	340	220
Fabric Thickness (mm)	0.64	0.52	0.19	0.29
Fabric Weight (g/m^2)	287.0	285.6	91.5	129.07
Cover Factor (100%)	70.8	87.8	61.2	61.4
Air-Permeability ($cm^3/cm^2/sec^{-1}$)	27.4	7.2	97.02	99.7

The results in Table 4.3 show that the bed sheet linen fabric has an air permeability of 27.4 $cm^3/cm^2/sec^{-1}$, the cotton has 7.2 $cm^3/cm^2/sec^{-1}$, the polyester-cotton has 97.02 $cm^3/cm^2/sec^{-1}$ and the polyester has 99.7 $cm^3/cm^2/sec^{-1}$. It can be seen from these values that the polyester and the polyester-cotton fabrics are more air permeable than the bed sheet linen and cotton fabrics. The cotton fabric has the lowest air permeability. When the bed sheet linen fabric is compared with all these fabrics, it is found that it has neither very low nor very high values of air permeability. On the basis of these results it can be said that bed sheet linen fabric has an intermediate porosity.

The factors which can affect air permeability by causing a change in the length of air flow paths through the thickness of the fabric are fabric and yarn construction. From Table 4.3, it can be seen that all four fabrics have different textile construction factors.

The main reason for the high air permeability values in the polyester and polyester-cotton fabrics was due to their cover factors. Cover factor is a term that is closely related to porosity. It is defined as the ratio of fabric surface occupied by yarns to the total fabric surface (Tortora & Merkel, 1996). It is a parameter based on fabric count and yarn linear density.

Cover factor is calculated using the formula:

$$D_w\ P_w + D_f\ P_f - 0.01\ D_w D_f P_w P_f$$

Where

D_w = diameter of warp and can be calculated by

$D_w = 0.0375\ \sqrt{N/\delta}$ ------------------ (1)

and N means yarn count in Tex and δ is fiber density in g/cm^3.

P_w = No. of warp ends/10 cm

D_f = diameter of weft yarn and can be calculated by equation (1)

P_f = No. of weft-picks/10 cm.

By using this formula cover factor of all four fabrics were calculated and listed in Table 4.3.

It can be seen from Table 4.3 that 100% cotton fabric used in the present study had the highest cover factor (87.8) which means that it had the most closely woven structure, resulting in the lowest air permeability (7.2 $cm^3/cm^2/sec^{-1}$). Similarly the RHC bed sheet linen fabric had a closely woven structure represented by a high cover factor (70.8). Accordingly, it also demonstrated relatively low air permeability (27.4 $cm^3/cm^2/sec^{-1}$).

On the other hand, the polyester/cotton and the polyester fabrics with lower cover factors, 61.2 and 61.4 respectively, showed significantly higher air perm abilities, 97.02 $cm^3/cm^2/sec^{-1}$ and 99.7 $cm^3/cm^2/sec^{-1}$ respectively.

It should be noted, though, that the large differences in air perm abilities also resulted from variations in fabric thickness. The later two fabrics (polyester/cotton 0.19 mm, polyester 0.29 mm) were much thinner than the first two fabrics (RHC bed sheet: 0.64 mm, 100%cotton: 0.52 mm).

These experimental results suggest that the cover factor and thickness of a fabric collectively determine its air permeability. A higher cover factor and a thicker fabric structure usually mean fewer continuous passages through the thickness of the fabric for moving air, thus lower air permeability.

4.3.2 Moisture Diffusion through Fabrics

For measuring moisture diffusion and moisture transportation in these materials, they were tested according to CAN/CGSB-4.2 No. 49-99 and Van Beest & Wittgen (VBW) test methods. Test results were obtained by using a SEA Automated Water Vapour Diffusion Apparatus.

For this test, the RHC bed sheet linen fabric was laundered according to AATCC-135 test method and then divided into four groups with respect to the number of laundering cycles. These groups include as received (with out laundering), 1 wash, 5 wash and 10 wash samples.

Appendices B & C respectively show the CGSB and VBW results obtained for moisture vapour & liquid diffusion of the bed sheet samples in the unused state and after different laundry cycles. The 100% cotton, polyester-cotton and 100% polyester fabrics were tested in the unused condition. Their CGSB & VBW test results are listed in Appendices D and E respectively.

Tables 4.3(a) and 4.3(b) were generated from appendices B & C. These tables show the results of the RHC bed sheet samples according to the CGSB and VBW methods.

Table 4.3(a) Bed Sheet Samples: CGSB Mode

Sample	Moisture Vapour Diffusion Resistance (Avg.)	Standard Déviation
As received	2.31 mm	1.04
1 wash	1.52 mm	0.13
5 wash	1.70 mm	0.37
10 wash	1.18 mm	0.18

Table 4.3(b) Bed Sheet Samples: VBW Mode

Sample	Moisture Vapour Diffusion Resistance (Avg.)	Standard Déviation
As received	-0.77 mm	0.9
1 wash	-1.15 mm	1.35
5 wash	-0.28 mm	0.57
10 wash	-0.53 mm	0.78

Table 4.3 (a) shows the average values of moisture vapour diffusion resistance in terms of still air. These results confirm the breathability of the bed sheet fabric samples in all four different

conditions. The breathability of fabrics means their ability to allow the passage of moisture vapour through them. The Sears standard (SEARS Specs, 2005) for fabrics described as breathable is less than 20 mm of still air; the lower the number, the more breathable the fabric.

The results in Table 4.3 (a) show that unused bed sheet sample had a value of 2.31 mm. After 1 wash or laundry cycle, samples obtained a value of 1.52 mm. This shows that breathability or moisture vapour diffusion resistance increased after 1 laundry cycle.

The 5 wash bed sheet sample's result value was 1.70 mm which shows that there was no significant difference between the values for the 1 wash and the 5 wash samples. But this shows that laundry cycles do have a significant effect on the breathability of textile materials.

The 10 wash bed sheet sample's result was 1.18 mm. When this result is compared with the unused sample and the other two washed samples, it can be said that as laundry cycles increase, breathability of textile material also increases. A possible explanation for such a phenomenon is that the mechanical forces in the laundry process changed the fabric and yarn structures, i.e., pore distribution within the yarns and between the yarns, although the total porosity of the fabric remained unchanged as discussed in section 4.3.1.

Similarly the results from Table 4.3(b) show the wicking capacity (transportation of liquid water) of the RHC bed sheet linen fabric in all four different conditions. These results indicate that there was no significant change between the as received sample and the 10 wash sample. Even the results following 1 wash and 5 washes show little variation. On the basis of these results it is hard to develop a relationship between laundry cycles and their effect on the wicking capacity of the textile fabrics in this study.

Results in these tables indicate that all four materials were breathable and had good wicking capacity. It can be seen from the table that the VBW resistance of these fabrics are negative numbers. This is an indication that all the fabrics have a higher wicking capacity than the VBW cell itself, in which a nonwoven protective membrane and a filter paper are placed immediately next to the water surface, as described in Chapter 3.

Figures 4.1and 4.2 were plotted to demonstrate the impact of laundry cycles on moisture vapour diffusion resistance of bed sheet samples. X-axis showed the laundry cycles while y-axis showed the average moisture vapour diffusion in mm.

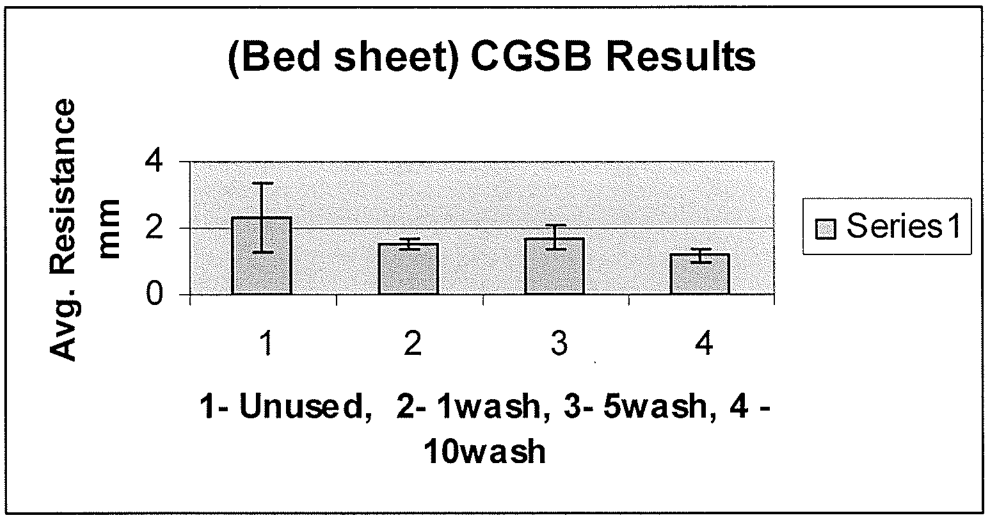


Figure 4.1(Bed Sheet CGSB Moisture Vapour Diffusion Results)

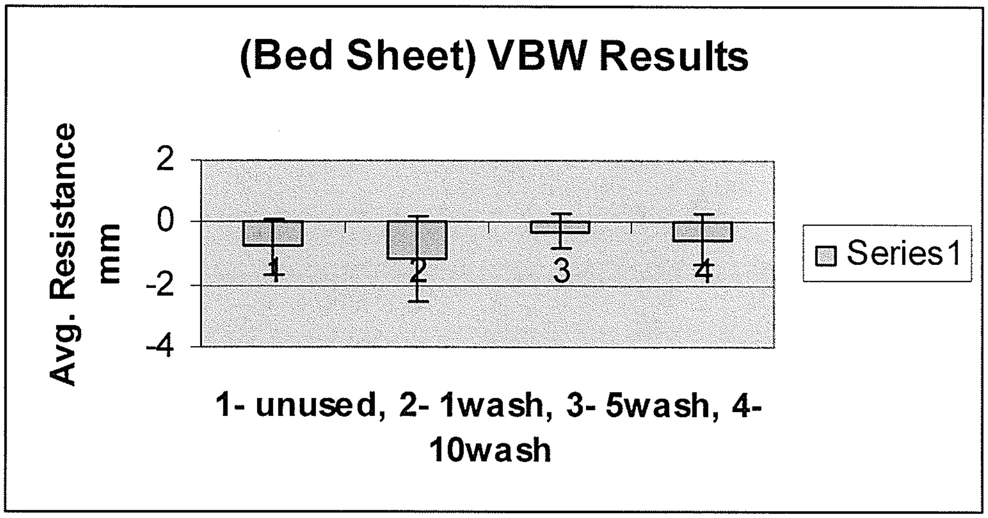


Figure 4.2 (Bed Sheet - VBW Moisture Vapour Diffusion Results)

Table 4.3 (c)

	Bed sheet	**Cotton**	**Polyester-Cotton**	**Polyester**
Thickness	0.64 mm	0.52 mm	0.19 mm	0.29 mm
Cover Factor (100%)	70.8	87.8	61.2	61.4
Air Permeability ($cm^3/cm^2/sec^{-1}$)	27.4	7.2	97.02	99.7
CGSB Value	2.31 mm	0.47 mm	0.29 mm	0.03 mm
VBW Value	-0.77 mm	-0.55 mm	-0.26 mm	-0.34 mm

Table 4.3 (c) shows the result of the 100% cotton, polyester/-cotton (65%/polyester, 35%/cotton) and 100% polyester fabrics in the unused state according to CGSB & VBW test modes. The table was developed from Appendices D & E to compare the breathability and wicking capacity of these materials with the unused RHC bed sheet linen. It also shows the relationship between air permeability, cover factor, porosity, breathability and wicking capacity

of these textile materials.

In the CGSB mode, the result for the 100% cotton was 0.47 mm, for the polyester-cotton was 0.29 mm and for the 100% polyester was 0.03 mm compared the value of 2.31 mm for the RHC bed sheet linen, which is 2.31 mm. It can be seen that the bed sheet linen was breathable according to the Sears standard but 100% cotton, polyester-cotton & polyester test fabrics were proven to be more breathable than the bed sheet linen.

Similarly in VBW mode, the moisture vapour diffusion resistance of the bed sheet linen was -0.77 mm, 100% cotton -0.55 mm, the polyester-cotton -0.26 mm and 100% polyester -0.34 mm of still air. Although the results indicate that these materials are breathable, they also show that their wicking capacity is very high.

The results show that the materials having higher air porosity were more breathable. Similarly the materials which had high air permeability, showed more wicking capacity as compared to the materials which have relatively less air porosity and breathability. The RHC bed sheet linen and 100% cotton fabrics had more thickness; therefore they had higher cover factors and lower air permeability, breathability and wicking capacity results. On the basis of these results it could be said that fabrics with low thickness and low cover factor showed higher air permeability, breathability and wicking capacity, such as the polyester-cotton and 100% polyester fabrics used in the comparative experimental studies.

All these four materials have different fabric and yarn specifications such as yarn linear density, yarn twist, fabric count, fiber content and cover factor. But it is known that moisture diffuses through the air spaces between the fibers and yarns, suggesting that this phenomena depends on yarn structure and fabric count. Diffusion is more likely to occur in fabrics that have larger interstices or open spaces within the structure. These interstices actually perform the role of pores within the structure. These pores can be effective in facilitating diffusion because of the fabric interstices between yarns and yarn interstices that are spaces between fibers within a yarn. The number and size of fabric interstices or pores in a given area of fabric depend on the fabric count, yarn linear density and yarn twist (Booth, 1968).

Fabrics referred to as having an open weave or open structured, means that they have relatively large fabric pores and water can diffuse through such fabrics more readily.

In the present study's case, all fabric specifications including cover factor were different from one another. But it could be said that the fabrics with a more open weave or structure were more breathable. In the case of the RHC bed sheet linen fabric, its breathability and wicking capacity appeared to cause an increase the amount of moisture when it is in direct contact with wet surfaces. This moisture accumulates on the skin surface of patients and disturbs an equilibrium state of the microclimate between the skin and fabrics. This moisture on the skin surface increases skin friction (Gwosdow et al 1986) and this could enhance the risk of skin damage.

Chapter 5: General Discussion & Conclusions

5.1 Conclusions

The role of textile products in the formation and prevention of skin lesions and pressure ulceration was studied. A survey study was conducted with the collaboration of Riverview Health Centre, Winnipeg, Manitoba. The prevalence of skin problems associated with textile products used by residents at Riverview was collected from the participants and statistically analyzed.

After statistical analysis, immobility of residents was determined to be the key factor of causing skin lesions and pressure ulcers. Immobility of patients helped to develop a prolonged interaction between skin and fabrics and might increase the chances of skin problems. Immobility confined patients to spend most of their time in beds and/or wheel chairs. In this situation, the type of bed sheet linens has been identified as the prime textile material which being in direct contact with the patient's skin has a significant influence on contributing to skin problems and pressure ulcers.

On the basis of these findings, the bed sheet linens routinely used at RHC were tested experimentally to determine their surface roughness, frictional properties, air permeability, moisture diffusion rate and water transportation properties.

Frictional properties and surface roughness of bed sheet linens were evaluated by a Kawabata Evaluation System. Bed sheet linens were divided into two groups, i.e., unused and 10 wash. Both groups were tested under dry and wet conditions. The experimental results showed that the presence of excessive moisture or water significantly increased the frictional resistance of the bed sheet linens which could result in a greater chance of damage to the skin.

These results also demonstrated that 10 laundry cycles have a little impact on the frictional properties of bed sheet linens. For fabric roughness, it was found that under dry conditions, the geometric roughness (SMD) values were higher compared to wet conditions for both unused and 10 wash samples. This difference was more significant for the unused linen compared to the 10 wash samples.

The most important experimental section of this study was to determine the water vapour transportation properties of the bed sheet linens. For this purpose, air permeability, breathability (water vapor diffusion rate) and the wicking capacity of the bed sheet linens were measured. In addition to the actual bed sheet linen routinely used at RHC, three other materials of different textile structures and fiber contents were included in the study. The objective of testing these materials was to compare their relative sensory and water transportation performances.

Air permeability apparatus was used to measure the air permeability of these four materials. The experimental results suggested that the cover factor and thickness of a fabric collectively determine its air permeability. Fabrics with higher cover factors and thicker textile structures usually have less pores or passages for moving air, thus making them less air permeable materials.

The moisture or liquid transportation properties of these four materials were measured by an SEA Automated Water Vapour Diffusion Apparatus (AWVDA). For these determinations the bed sheet linens were divided into four groups. These groups were unused, 1 wash, 5 wash and 10 wash samples. The experimental results showed that laundry cycles may influenced the rate of water vapour transmission through these textile materials. But for the wicking capacity of liquid moisture, results indicated that there was no significant difference between the tested values of the unused and laundered samples.

The comparative results between the RHC bed sheet linens and the other three textile materials revealed that the materials having higher air permeability are more breathable and have higher wicking and water vapour diffusion capacities as compared to the materials having relatively lower air permeability and breathability. These results also suggested that the fabrics with lower cover factor and thickness showed higher breathability, water vapour diffusion and wicking capacity.

These findings helped to confirm that surface frictional properties and moisture transportation properties of textile materials play an important role in causing or preventing skin lesions and pressure ulcers.

5.2 Suggestions for Future Studies

The following are suggestions for further research work in this area:

- It seems that the sample size of participants in this study was relatively small to obtain reliable and useful information. Therefore it is suggested that in future more subjects should be involved in research to obtain more reliable and practical results.
- As lack of mobility has been identified as the key factor that influences the formation and prevention of bedsores, the selection of appropriate bed sheet linen fabric is an important issue in addressing the problems of skin lesions and pressure ulcers. In further studies, more health care facilities should be involved and a wide range of bed sheet linens should be tested. If all Winnipeg regional health care facilities were to be involved, then more informative, reliable and helpful results could be achieved.
- In this study, the researchers did not have direct access or interaction with patients. All the information and data were collected by the healthcare providers. In future, there should be

some arrangements for researchers to have direct supervised interaction with patients, so they could get first hand patient information and personal opinions.

- Another limitation in this study was that we did not determine the impact of frictional surface and roughness properties of the textiles directly on human skin. In future studies, direct in vivo experiments should be conducted on the human skin to evaluate the influence of various textiles properties. These investigations would be essential for the design and development of superior bed linen fabrics tat cause minimal damage to human skin under typical patient pressures and humidities.

Bibliography

AATCC (2004). Test Method 135. Dimensional Changes of Fabrics after Home Laundering. American Association of Textile Chemists and Colorists, Research Triangle Park, NC.

Allman, R.M., & Goode, P.S., et al. (1995). Pressure ulcer risk factors among hospitalized patients with activity limitation. Journal of the American Medical Association, 273 (11), 865.

Amlung, S., Miller, B., & Bosley, L. (2001). The 1999 National Pressure Ulcer Prevalence Survey: a bench marking approach. Advances in Skin & Wound Care, 14, 297-302.

ASTM (2002). Standard test method for thickness of textile material. (Test Method D1777-96). Philadelphia, PA: American Society for Testing and Materials.

ASTM (2002). Standard test method for measuring fabric count in woven fabrics. (Test Method D3775). Philadelphia, PA: American Society for Testing and Materials.

ASTM (2002). Standard test method for measuring fabric weight (Test Method D3776-96). Philadelphia, PA: American Society for Testing and Materials.

Barbenel, J.C., Jordan, M.M., Nicol, S.M. (1977). Incidence of pressure sore in the greater Glasgow health board area. The Lancet, 2: 548-550.

Barratt, E. (1999). Pressure sores in intensive care. Intensive Therapy & Clinical Monitoring, Sept/Oct, 158-167.

Baumgarten, M., & Margolis, D.J., et al. (2006). Pressure ulcers among elderly patients early in the hospital stay. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 61, 749-754.

Beckrich, K., & Aronovitch, S. (1999). Hospital-acquired pressure ulcers: a comparison of costs in medical vs. surgical patients. Nursing Economics, 17, 263-271.

Bennett, G., Dealey, C., & Posnett, J. (2004). The cost of pressure ulcers in the UK. Age and Ageing, 33, 230-235.

Bergstrom, N., Braden, B.J., Laguzza, A., & Holman, V. (1987). The Braden Scale for predicting pressure sore risk. Nursing Research, 36, 205-210.

Berlowitz, D, R., & Wilking, S.V.B. (1989). Risk factors for pressure sores: A comparison of cross-sectional and cohort-derived data. Journal of the American Geriatrics Society, 37(11), 1043-1050.

Bliss, M.R. (1993). Aetiology of pressure sores. Reviews in Clinical Gerontology, 3, 379-397.

Booth, J.E. (1968). Principles of textile testing: an introduction to physical methods of testing textile fibers, yarns and fabrics. London: Heywood Books.

CAN/CGSB (1990). Textile test method for conditioning the samples (4.2-M77, No.2). Ottawa: ON. Canadian Standard General Board.

CAN/CGSB (1997). Textile test method – Air permeability (4.2-M89, No.36). Ottawa: ON. Canadian Standard General Board.

CAN/CGSB (1999). Textile test method for measuring "resistance of materials to water vapour diffusion" (4.2 No.49-99). Ottawa: ON. Canadian Standards General Board.

Cannon, B.C., & Cannon, P.J. (2004). Management of pressure ulcers. American Journal of Health-System Pharmacy, 61 (9), 1895-1905.

Clarke, M., & Kadhom, H.M. (1988). The nursing prevention of pressure sores in hospital and community patients. Journal of Advanced Nursing, 13, 365-373.

Collier, B.J., & Epps, H.E. (1999). Textile Testing and Analysis (pp 288-291). New Jersey: Printice-Hall.

Defloor, T. (1999). The risk of pressure sores: a conceptual scheme. Journal of Clinical Nursing, 8, 206-216.

Dinsdale, S.M. (1974). Decubitus ulcers: Role of pressure and friction in causation. Archives of Physical Medicine and Rehabilitation, 55, 147-152.

Elsner, P., Hatch, K., & Walter, W.A. (2003). What textile engineers should know about the human Skin? Textiles and the Skin (pp.24). Basel: KARGER.

European Pressure Ulcer Advisory Panel (EPUAP). (1999). Guidelines on treatment of pressure ulcers. EPUAP Review, 1, 31-33.

Fader, M., Bain, D., & Cottenden, A. (2004). Effects of absorbent incontinence pads on pressure management mattresses. Journal of Advanced Nursing, 48(6), 569-574.

Ferrell, B.A., Josephson, K., Norvid, P., & Alcorn, H. (2000). Pressure ulcers among patients admitted to home care. Journal of the American Geriatrics Society, 48, 1042-1047.

Fleurence, R.L. (2005). Cost-effectiveness of pressure-relieving devices for the prevention and treatment of pressure ulcers. International Journal of Technology Assessment in Health Care, 21 (3), 334-342.

Guralink, J.M., Harris, T.B., White, L.R., et al. (1988). Occurrence and predictors of pressure ulcers in the national health and nutrition examination survey follow up. Journal of the American Geriatrics Society, 36, 807-812.

Gwosdow, A.R., et al. (1986). Skin friction and fabric sensations in neutral and warm environments. Textile Research Journal, 56 (9), 574-580.

Hatch, K. (1993). Textile Science. Minneapolis, MN: West Publishing Company.

Hatch, K.L., Markee, N.L., Wilson, D., & Maibach, H.I. (1987). Fabric changes in human skin: In vivo stratum corneum water content and water evaporation. Textile Research Journal, 47, 583-591.

Hatch, K.L., Woo, S.S., Barker, R.L., Radhakrishnaiah, P., Markee, N.L., & Maibach, H.I. (1990). In vivo cutaneous and perceived comfort response to fabricPart I: Thermephysiological comfort determinations for three experimental knit fabrics. Textile Research Journal, 7, 405-412.

Hatch, K.L., Markee, N.L., Maibach, H.I., Barker, R.L., Woo, S.S., & Radhakrishnaiah, P. (1990). 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, 9, 510-519.

Hatch, K.L., Markee, N.L., Maibach, H.I., Barker, R.L., Radhakrishnaiah, P., & Woo, S.S. (1990). In vivo cutaneous and perceived comfort response to fabric. Part IV: Perceived sensations to three experimental garments worn by subjects exercising in a hot, humid environment. Textile Research Journal, 10, 551-568.

Hatch, K.L., Markee, N.L., Prato, H.H., Zeronian, S.H., Maibach, H.I., Kuehl, R.O., & Axelson, R.D. (1992). In vivo cutaneous and perceived comfort response to fabric. Part V: Effect of fiber type and fabric moisture content on stratum corneum hydration. Textile Research Journal, 11, 638-647.

Hatch, K.L., Prato, H.H., Zeronian, S.H., & Maibach, H.I. (1997). In vivo cutaneous and perceived comfort response to fabric. Part VI: The effect of moist fabrics on stratum corneum hydration. Textile Research Journal, 12, 926-931.

Herman, L.E., & Rothman, K.F. (1989). Prevention, care and treatment of pressure ulcers in intensive care unit patients. Journal of Intensive Care Medicine, 4, 117-123.

Hofman, A., et al. (1994). Pressure sores and pressure-decreasing mattresses: controlled clinical trial. Lancet, 343, 568-571.

Jolley, D.J., et al. (2004). Preventing pressure ulcers with the Australian Medical Sheepskin: An open-label randomized controlled trial. Medical Journal of Australia, 180 (4), 324-327.

Kenedi, R. M. (1976). Bedsore biomechanics. Baltimore: University Park Press.

Kosiac, M. (1961). Etiology of decubitus ulcers. Archives of Physical Medicine and Rehabilitation, 42, 19-29

Li, Y. (2001). The Science of Clothing Comfort (pp 66-67). Manchester: UK. The Textile Institute.

Maklebust, J., & Sieggreen, M. (2001). Pressure ulcers: guidelines for prevention and management (pp 24-26). Pennsylvania: Springhouse.

Marchand, A. C., & Lidowski, H. (1993). Reassessment of the use of genuine sheepskin for pressure ulcer prevention and treatment. Decubitus, 6 (1), 44-47.

Margareta, L., & Mitra, U., et al. (2004). Immobility- a major risk factor for development of pressure ulcers among adult hospitalized patients a prospective study. Scandinavian Journal Of Caring Sciences, 18 (1), 57-64.

Meehan, M. (1994). National pressure ulcer prevalence survey. Advances in Wound Care, 7, (5), 27-37.

Morison, M, J. (2001). The prevention and treatment of pressure ulcers (pp.65). Toronto: MOSBY.

National Pressure Ulcer Advisory Panel (NPUAP). Staging Report 2003. Retrieved October 15, 2005, from http://www.npuap.org/position6.html

NCSU (2006). Textile Protection and Comfort Centre: Fabric Hand Lab. Retrieved November 21, 2006, from http://www.tx.ncsu.edu/tpacc/comfort/fabric_hand_lab.html

Parakkal, P.F., & Montagana, W. (1974). The structure and function of skin. New York:

Academic Press.

Pase, M.N. (1994). Pressure relief devices, risk factors, and development of pressure ulcers in elderly patients with limited mobility. Advances in Wound Care, 7, 38-42.

Prentice, J.L., & Stacey, M.C. (2001). Pressure ulcers: the case for improving prevention and management in Australian health care settings. Primary Intention, 9, 111-120.

Pryczynska, E. (2000). Anti-bedsore sheet fabrics assuring comfort of usage for the permanently immobile people. Scientific Project.

Pryczynska, E., et al. (2003). Sheet fabrics with biophysical properties as elements of joint prevention in connection with first and second generation pneumatic anti-bedsore mattresses. Fibers & Textiles in Eastern Europe, 11(4), 50-53.

S.E.A. (2006). Automated Water Vapour Diffusion Apparatus System Manual. S.E.A. Engineering Company Inc.

SEARS SPECS (2005). The Sears Standard for Breath-able Textiles. Sears Canada.

Snycerski, M., & Frontczak-Wasiak, I. (2004). A functional woven fabric with controlled friction coefficients preventing bedsores. Autex Research Journal, 4 (3), 137-142.

Swinscon, T.D.V., & Campbell, M.J. (2002). Statistics at Square One (pp 52-54 & 147). London: BMJ Books.

Thomas, D.R. (2001). Prevention and treatment of pressure ulcers: What works? What doesn't?. Cleveland Clinic Journal of Medicine, 68 (8), 704-722.

Tortora, P.G., & Merkel, R.S. (1996). Fairchild's Dictionary of Textiles. New York: Fairchild Publications.

Vanderwee, K., Grypdonk, M.H.F., & Defloor, T. (2005). Effectiveness of an alternating pressure air mattress for the prevention of pressure ulcers. Age and Ageing, 34, 261-267.

Woodbury, M.G., & Houghton, P.E. (2004). Prevalence of pressure ulcers in Canadian healthcare settings. Ostomy/Wound Management, 50 (10), 22-38.

Wysocki, A.B. (1995). A review of the skin and its appendages. Advances in Wound Care, 8, (2), 53-64.

Young, L. (1989). Pressure ulcer prevalence and associated patient characteristics in one long-term care facility. Decubitus, 2 (2), 52.

Zimmerer, R. E., Lawson, K.D., and Calvert, C.J. (1986). The effects of wearing diapers on skin. Pediatric Dermatology, 3, 95-101.

APPENDIX A

FORM I: Data Collection Form

Participant Code Number ____________________
Date____________________

Part A: Chart information to be transcribed

1. Gender of Resident: a) Female b) Male

2. Date of birth ____________ 3. Age: ____________

4. Weight: ____________ 5. Incontinence: ☐ Yes ☐ No

	Location (See legend)	Stage (See legend)	Present on admission to RHC?	
1			Yes	No
2			Yes	No
3			Yes	No
4			Yes	No
5			Yes	No

Skin Treatment: (check all that apply during last 7 days- pressure ulcers only)

Pressure reducing device(s) for chair
Preventative or protective skin care e.g. barrier cream
Pressure reducing device(s) for bed
Application of ointments/medication (no dressing)
Special turning/repositioning program
Application of dressings (with/without topical medications)
Nutrition or hydration intervention to manage skin problems
None of above

LEGEND

LOCATION:

1. Back of head 2. Right ear 3. Left ear 4. Left shoulder 5.Right shoulder 6. Left elbow	9. Right hand 10. Left fingers 11. Right fingers 12. Right Scapula 13. Left scapula 14. Vertebrae 15.Sacrococcygeal	17.Left trochanter 18. Right buttock 19. Left buttock 20. Right thigh 21. Left thigh 22. Right knee	24. Right lower leg 25. Left lower leg 26. Right leg stump 27. Left leg stump 28. Right heel 29. Left heel 30. Right lateral	31. Left lateral foot 32. Right ankle (inner) 33. Right ankle (outer) 34. Left ankle (inner)

7. Right elbow 8. Left hand	area 16. Right trochanter	23. Left knee	foot	35. Left ankle (outer) 36. Right toe(s) 37. Left toe(s)
STAGES:				

Stage 1. A persistent area of skin redness (without a break in the skin) that does not disappear when pressure is relieved.
Stage 2. A partial thickness loss of skin layers that presents clinically as a abrasion, blister or shallow crater.
Stage 3. A full thickness of skin lost, exposing the subcutaneous tissues- presents with a deep crater with or without undermining adjacent tissue.
Stage 4. A full thickness of skin and subcutaneous tissue is lost, exposing muscle or bone.
Stage 5. Unstable due to necrosis.

6. Pressure ulcer identified in the last six months: ☐ Yes ☐ No

7. Skin Lesion (other than pressure ulcers) identified in the last six months:☐ Yes ☐ No

Part B: RHC pressure ulcer prevalence monitoring information to be transcribed:

1. Date of Assessment ____________________ 2. Braden Score (NS-72:03-09):______________

3. Incidence of skin lesion or ulcer

a) ☐ No Ulcers
b) ☐ Skin Lesion other than pressure ulcers

ıer Skin problems or lesions: (check all that apply during last 7 days)		
Abrasions, bruises	☐	Vascular ulcer (e.g. venous stasis, arterial or both), diabetic
t ulcer		
Burns (second or third degree)	☐	Rashes (e.g. intertrigo, eczema, drug rash, heat rash, herpes
;ter)		
Surgical wounds	☐	Other open lesions (e.g. cancer)
Skin tears or cuts (other than surgery)		

c) ☐ Pressure ulcers

Part C: Interviews with the residents' care giving staffs

xtile products use by residents	
Textile Product	Frequency and length of time for using

Could you please let me know the fiber content of the <u>bed sheet(s)</u> the resident is using, or, let me take a look at the label to read the information? ______________________________ Could you please let me know the fiber content of the <u>pillowcase(s)</u> the resident is using, or, let me take a look at the label to read the information? ______________________________ Could you please let me know the fiber content of the <u>pajama(s), or, other clothing worn next to skin for night sleep</u> the resident is using, or, let me take a look at the label to read the information? ______________________________	What is the approximate time he/she will spend on a bed everyday? Napping? ________ hours/day Or, from about ______am/pm to _______ am/pm Night sleep ________ hours/day Or, from about ______am/pm to _______ am/pm Total ________ hours/day
Does the resident use wheelchair? Yes No If yes, could you please let me know the fiber content of the <u>Seat cover</u> the resident is using, or, let me take a look at the label to read the information? ______________________________	What is the approximate time he/she will spend on a wheelchair everyday? ________ hours/day Or, from about ______am/pm to _______ am/pm
Could you please let me know the fiber content of the <u>socks</u> the resident is using, or, let me take a look at the label to read the information? ______________________________	What is the approximate time he/she will spend on walking everyday? ________ hours/day Or, from about ______am/pm to _______ am/pm

Textile products provided by the Riverview Health Center in special cases or treatments	
Could you please let me know the fiber content of the <u>under pants</u> the resident is using, or, let me take a look at the label to read the information? ____	

	Textile Product	Frequency and length of time for using
1	Is the resident incontinent? Yes No If yes, what are the incontinent products that are used? Indicate name ____________________ Brand name ____________________ If more than one type: Indicate name ____________________ Brand name ____________________	________ hours/day Change ______ times a day ________ hours/day Change ______ times a day
2	Does the resident use hip protector or similar product? Yes No Indicate name ____________________ Brand name ____________________	________ hours/day
3	Does the resident use lifting devices? Yes No Indicate name ____________________ Brand name ____________________ If more than one type: Indicate name ____________________ Brand name ____________________	________ time/day ________ min for each use ________ time/day ________ min for each use

Appendix B

(Bed sheet) CGSB Test Mode Results

Final Results: Unused Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	2.41	0.446	2408.08	5.31
Test Condition 1	2.04	0.328	2454.63	7.62
Sample				2.31

Final Results: 1 Wash Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	2.26	0.418	2386.30	5.61
Test Condition 1	1.80	0.333	2417.43	7.13
Sample				1.52

Final Results: 5 Wash Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	2.32	0.429	2410.19	5.57
Test Condition 1	1.78	0.329	2435.74	7.27
Sample				1.7

Final Results: 10 Wash Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	2.15	0.398	2420.65	5.96
Test Condition 1	2.11	0.336	2448.96	7.14
Sample				1.18

Appendix C

(Bed sheet) VBW Test Mode Results

Final Results: Unused Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.87	0.430	2384.95	5.44
Test Condition 1	4.44	0.493	2340.60	4.67
Sample				-0.77

Final Results: 1 Wash Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.54	0.393	2379.35	5.94
Test Condition 1	4.40	0.489	2330.31	4.79
Sample				-1.15

Final Results: 5 Wash Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	4.00	0.444	2395.22	5.33
Test Condition 1	4.14	0.460	2340.40	5.05
Sample				-0.28

Final Results: 10 Wash Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	4.47	0.497	2207.97	5.53
Test Condition 1	4.47	0.496	2367.97	5.00
Sample				-0.53

Appendix D

(Fabrics) CGSB Test Mode Results

Final Results: Unused Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	2.41	0.446	2408.08	5.31
Test Condition 1	2.04	0.328	2454.63	7.62
Sample				2.31

Final Results: Cotton 100%

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.81	0.424	2442.29	6.51
Test Condition 1	2.53	0.493	2426.25	7.08
Sample				0.47

Final Results: Poly-Cotton 65/35

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	4.05	0.451	2438.20	5.40
Test Condition 1	3.50	0.574	2410.29	5.69
Sample				0.29

Final Results: Polyester 100%

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.39	0.471	2443.48	6.03
Test Condition 1	2.15	0.504	2453.75	6.06
Sample				0.03

Appendix E

(Fabrics) VBW Test Mode Results

Final Results: Unused Bed-Sheet

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.87	0.430	2384.95	5.44
Test Condition 1	4.44	0.493	2340.60	4.67
Sample				-0.77

Final Results: Cotton 100%

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.51	0.390	2399.78	6.43
Test Condition 1	3.76	0.417	2374.11	5.88
Sample				-0.55

Final Results: Poly-Cotton 65/35

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.90	0.606	2359.15	5.37
Test Condition 1	4.15	0.693	2367.11	5.11
Sample				-0.26

Final Results: Polyester 100%

	Avg. Moist Diff. (g)	Avg. Moist Diff. Rate (mg/s)	Avg. Partial Press. (mg/s)	Avg. Res. R/R_{air} (mm S.Air)
Blank Runs	3.90	0.606	2359.15	5.37
Test Condition 1	4.07	0.927	2307.24	5.03
Sample				-0.34