The influence of different types of barrier creams on skin barrier function

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Mini-dissertation submitted in partial fulfilment of the requirements for the degree *Master of Science* in Occupational Hygiene at the Potchefstroom Campus of the North-West University

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November 2012

Preface

For this mini-dissertation, it was decided to use the article format. For uniformity the whole dissertation is written according to the guidelines of the chosen journal for potential publication which is the *Annals of Occupational Hygiene*. The journal requires that the references in the text should be in the form Jones (1995), or Jones and Brown (1995), or Jones *et al.* (1995) if there are more than two authors. References should be listed in alphabetical order by name of first author, using the Vancouver Style of abbreviation and punctuation.

Chapter 1 contributes a brief introduction about barrier creams and their function and an overview of the skin's barrier function. Furthermore, it includes the problem statement, research question and research objectives. Chapter 2 consists of an in-depth discussion of barrier creams, their function and different types of barrier creams. The skin anatomy and parameters influencing skin barrier function and skin barrier measurement will be discussed. Chapter 3: the influence of different types of barrier creams on skin barrier function, is written in article format. All tables and figures are included here, along with text, to present the findings of this study in a readable and understandable format. The article will be submitted to the *Annals of Occupational Hygiene* for peer reviewing and publication. Chapter 4 includes a final summary and conclusion, as well as recommendations for future studies. Chapter 5 consists of the Appendix. *The Annals of Occupational Hygiene* is published by Oxford University Press for the British Occupational Hygiene Society, therefore a British English style is used throughout this mini-dissertation.

Acknowledgements

I would firstly like to thank my Heavenly Father for giving me the strength and determination to carry out this study and for knowing His plans are greater than mine.

- I would like to thank my parents Christo and Sonette du Plessis for giving me the opportunity to study and for always believing in me and their unconditional love and motivation.
- My brother Christo, participating as one of my test-subjects and always helping me in every possible way.
- Gerhard, for your understanding and endless care through the duration of my project.
- Anja Franken for her valuable guidance as my supervisor and her continuous advice and encouragement.
- Prof Eloff for his knowledge and experience.
- Ruan Kruger for offering his help with my statistical analysis.
- Prof Lesley Greyvenstein for language editing.

Author's Contribution

Name	Contribution
Ms S du Plessis	• Designing and planning of the study; • Literature searches, interpretation of data and writing of article; • Execution of all monitoring processes.
Ms A Franken	• Supervisor • Assisted with approval of protocol, interpretation of results and documentation of study; • Giving guidance with scientific aspects of the study.
Prof FC Eloff	• Co-supervisor • Assisted with designing and planning of the study, approval of protocol, interpretation of results and documentation of study.

The following statement from the co-authors that confirms each individual's role in the study:

**I declare that I have approved the above mentioned article and that my role in the study as indicated above is representative of my actual contribution and that I hereby give my consent that it may be published as part of S du Plessis, M.Sc. (Occupational Hygiene) mini-dissertation.*

Ms A Franken
(Supervisor)

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Abstract

Title: The influence of different types of barrier creams on skin barrier function.

Aims and objectives:

The research aims and objectives of this study were: Firstly to determine the positive effects and possible disadvantages of three types of barrier creams on skin barrier function by determining skin barrier function by measuring stratum corneum hydration transepidermal water loss (TEWL) and skin surface pH. Secondly to compare different racial skin types (African skin to Caucasian skin) by determining the effects of barrier cream on skin barrier function. Finally to compare the effect of the three different barrier creams on four different anatomical areas.

Methods:

Thirty eight non-smoking male test subjects took part in this study where three different types of barrier creams were tested on their arms and hands in a controlled laboratory environment. The thirty eight test subjects consisted of nineteen African and nineteen Caucasian test subjects. Three parameters were measured namely TEWL, stratum corneum hydration and pH condition of the skin. TEWL was measured using a Vapometer (Delfin Technology Ltd. Finland). The Multi probe Adapter system (MPA) (Courage and Khazaka, Germany) was used with a temperature and humidity sensor and with the following probes all from Courage and Khazaka, Germany: a Corneometer measuring skin hydration and a pH-Meter measuring skin surface pH. The measurements were repeated on each of the four sampling areas (forearm, wrist, back of hand and palm) with a reasonable time interval between each measurement. After the baseline measurement the barrier cream was applied by the researcher on the test subjects' dominant arm. The long term effects were determined after the baseline measurement in intervals of 2 hours. Directly after each measurement the barrier cream was reapplied.

Results:

Gloves In A Bottle™ increased stratum corneum hydration, had no effect on TEWL and increased skin surface pH, whereas Reinol™ increased stratum corneum hydration and decreased TEWL and had no effect on pH values. Travabon™ decreased stratum corneum hydration and TEWL and had no effect on skin surface pH. The results indicated that there were significant differences between Caucasian and African test subjects with the use of barrier creams, because of the baseline differences and the reaction to barrier creams showed different results. There were also statistically significant differences in the four different anatomical areas where the barrier creams were applied.

Conclusion:

Barrier creams are beneficial in the workplace, although it should be taken into consideration that different ethnicities react differently to barrier creams under different workplace situations and therefore this should be taken into account when selecting a barrier cream.

Key words:

Barrier cream, skin barrier function, hydration, TEWL, pH, racial differences

Opsomming

Titel: Die invloed van verskillende tipes velgrensrome op die velgrensfunksie.

Doelstellings en doelwitte:

Die navorsingsdoelstelling en –doelwitte van hierdie studie was: Eerstens om drie verskillende tipes velgrensrome met mekaar te vergelyk, om voordele en moontlike nadele te bepaal. Tweedens om die velgrensfunksie te bepaal deur stratum korneum hidrasie, trans-epidermale waterverlies (TEWV) en vel oppervlak pH te meet. Derdens om die verskillende effekte van velgrensrome in versillende rasse te bepaal (Kaukasier en Afrikaan). Laastens om die drie verskillende velgrensrome te vergelyk op vier verskillende anatomiese areas.

Metodes:

Drie verskillende velgrens rome is getoets op die arms en hande van agt en dertig nie-rokende manlike proefpersone, in ‘n gekontroleerde labarotorium omgewing. Die agt en dertig proefpersone het bestaan uit negentien Kaukasier mans en negentien Afrikaan mans. Die parameters wat gemeet was, is stratum korneum hidrasie, trans-epidermale water verlies (TEWV) en pH van die vel oppervlak. TEWV was bepaal deur ‘n Vapometer (Delfin Technology Ltd. Finland) te gebruik. Die Multi probe Adapter sisteem (MPA) van (Courage and Khazaka, Germany) was gebruik om temperatuur en humiditeit te bepaal, ‘n Corneometer vir die meet van velhidrasie en ‘n pH-Meter wat vel oppervlak pH bepaal. Elke meting is herhaal op vier van die meet areas (voorarm, gewrig, agterkant van hand en palm) met tyd intervalle.

Resultate:

Gloves In A Bottle™ het velhidrasie en pH verhoog, maar het geen effek op TEWV getoon nie, Reinol™ het velhidrasie verhoog met ‘n verlaging van TEWV en geen effek op pH nie. Travabon™ het TEWV en velhidrasie velaag met geen effek op pH nie. Die resultate dui dat daar geen betekenisvolle effekte tussen Kaukasier proefpersone en Afrikaan proefpersone was met die gebruik van velgrensrome nie, omdat basislyn waardes verkillende reaksies getoon het.

Samevatting:

Velgrensrome is voordelig in die werksplek maar wanneer ‘n velgerensroom geselekteer word moet rasse verskille en die verkillende werksplek omstandighede in ag geneem word.

Sleutelterme:

Velgrensrome, velgrensfunksie, velhidrasie TEWV, pH, rasse verskille

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List of Symbols and Abbreviations

Symbols and units

%	Percentage
°C	Degrees Celsius
>	Larger than
<	Smaller than
±	Plus-minus
$g\ m^{-2}\ h^{-1}$	Water vapour flux density
mm	Millimetre
µm	Micrometre
™	Trademark

Abbreviations

pH	Hydrogen ion concentration
SD	Standard deviation
TEWL	Transepidermal water loss
UK	United Kingdom
USA	United States of America

CHAPTER 1

INTRODUCTION

1.1 Overview

The skin is the largest organ of the body making it extremely vulnerable to the outside world. According to Proksch *et al.* (2008), the skin's most important function is to form an effective barrier between the "inside" and "outside" of a human being. Knowledge of the anatomical structure of the skin is important for a better understanding of the barrier function, penetration of substances, absorption of chemicals and immunological aspects of skin in response to external factors. In the workplace industry the human skin is exposed to a number of different substances on a daily basis depending on the activities and work-site. These substances include: water-soluble materials, acids, alkalis, dust, cement, metal-working oils, dirt and grime (Schliemann *et al.,* 2012).

Barrier creams are used to prevent penetration and absorption of these harmful contaminants and irritants into the skin. Barrier creams are not meant for treatment of contact dermatitis but rather for prevention when protective gloves cannot be worn. Barrier creams are recommended to be used in the prevention of occupational contact dermatitis as well as prevention of cutaneous damage (Berndt *et al.,* 2000). Barrier creams act as a nonpermeable barrier separating the skin from extreme workplace exposures. These barrier creams are absorbed into the superficial layer of the epidermis and are not removed when conventional hand washing takes place (Alvarez *et al.,* 2001).

There is an ethnic difference in the skin surface pH that demonstrates that African skin has a lower pH than Caucasian skin (Fluhr *et al*., 2008). In a study by Berardesca and Maibach (2003) *in vitro* measurements of transepidermal water loss (TEWL) were higher for African skin when compared to Caucasian skin, although measurements *in vivo* did not indicate any difference in TEWL. Based on a chemical and mechanical challenge the stratum corneum barrier function seems stronger in darker skin subjects (Rawlings, 2010). There are controversial studies when it comes to differences in ethnic groups' stratum corneum hydration, while some studies show no differences (Fluhr *et al.,* 2008).

Table 1: The three different types of barrier creams used in this study, the product ingredients and applications (Gloves In A Bottle, 2010; Stoko, 2010; Reinol, 2012).

TYPE OF BARRIER CREAM	**WATER-REPELLENT**	**OIL-REPELLENT**	**SILICONE-REPELLENT**
PRODUCT	**Reinol Skingard™**	**Travabon™**	**Gloves In A Bottle™**
USE	Wet-work, prevention to water-soluble irritants.	Oils, greases or other oil soluble substances	General protection from both water-soluble and organic agents.
INGREDIENTS	*Cannot be obtained from manufacturers. *No ingredients information available on packaging of product.	• Aqua (Water) • Talc • Sodium cocoyl Isethionate • Glycerin • Silica • Glyceryl Stearate • Laureth-10 • Bentonite • Xanthan Gum • Algin • Sodium Phosphate • Parfum • Lactic acid • Potassium Sorbate • Dioctyl sodium sulfosuccinate • Silver chloride • Propylene glycol • Titanium dioxide	• Purified water • Dimethicone • Stearic Acid • Glycerin • Cetyl Alcohol Isopropyl Myristate • Stearyl Alcohol • Triethanolamine • Xantham Gum • Hypromellose • VP/Eicosene Copolymer • Streeareth-21 • Phenoxyethanol
MANUFACTURER'S INSTRUCTIONS	Apply several times daily especially after washing.	Apply before starting work and after any breaks. Must be applied after sweating or contact with water.	Lasts up to 4 hours or more. For continued protection reapply during the day.

1.2 Barrier function parameters and factors influencing skin barrier measurement

Stratum corneum hydration, transepidermal water loss (TEWL) and skin surface pH are important factors that provide information about the function of the skin barrier and barrier permeability (Alanen *et al.,* 2004; Darlenski *et al.,* 2009). These factors will be discussed in Chapter 2 along with endogenous, exogenous and environmental factors and how these factors influence skin barrier measurements. This study will focus on the influence of barrier creams on the skins' barrier function, assessing not only the advantages but also the disadvantages.

Skin barrier function was determined by measuring transepidermal water loss (TEWL), stratum corneum hydration and skin surface pH.

Measuring hydration of the stratum corneum provide information on the biophysical properties and function of the skin barrier (Alanen *et al.,* 2004). TEWL assesses the epidermal barrier and provides information on permeability barrier status under normal, experimentally perturbed or diseased conditions (Darlenski *et al.,* 2009). Different racial skin types (African skin and Caucasian skin) was examined to determine if these skin types react differently to barrier creams.

1.3 Problem statement

Barrier creams are designed to protect the skin against harmful risk factors that occur in the workplace, and build up a diffusion barrier between the skin and irritant. Barrier creams are a method to protect the skin, however, they can also exert negative effects on skin hydration and skin barrier function if there are no correct instructions or guidance (Fluhr *et al.,* 2007). Occlusion can occur when the barrier cream formulation influences the stratum corneum hydration. Experimental studies also show that some creams can delay the contact with certain substances, whereas others enhance the penetration of the hazardous substance (Fluhr *et al.,* 2007; Schliemann, 2007).

The precise instructions for consumer use should be specific with regard to regular and frequent application for a barrier cream to be effective. Adequate amounts must be applied by the worker regularly during the workday to cover the skin surface being exposed, however the precise amount that should be applied is never specified by the manufacturers. Terms such as regularly, pea size amount/spoon-full are the only indications given to the consumer. The actual amount of barrier cream that should be applied by a worker still needs further investigation (Schliemann *et al.,* 2012).

1.4 Research question

Barrier creams act as protective creams for prevention of exposure to allergens, as well as harmful chemical and physical agents in the workplace. A study by Lushniak *et al.* (2003) showed that protecting a worker from exposure is an important task and that there is controversy about whether barrier creams are effective. Little is known about the effect of barrier cream on the underlying skin barrier function. Therefore stating the question: Does skin barrier creams have any negative effects on skin barrier function with regards to stratum corneum hydration, TEWL and skin surface pH? The second question: How will racial skin types, such as African and Caucasian, differ from each other in terms of their reaction following the application of barrier creams?

1.5 Research Objectives

General objective:

To determine the positive and possible negative effects of three types of skin barrier creams on skin barrier function.

Specific objectives:

- To determine skin barrier function by measuring stratum corneum hydration, transepidermal water loss (TEWL) and skin surface pH, when comparing the effects of three different types of barrier creams on the skin barrier function.

- To compare Caucasian and African skin with regard to the effects of barrier creams on skin barrier function.

- To compare the effects of the three different barrier creams on four different anatomical areas of the arms and hands.

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CHAPTER 2

LITERATURE STUDY

Introduction

The skin is the first line of defence of the body, that serves as a protecting barrier and, therefore, the skin anatomy and structure will be described in terms of skin barrier function. Knowledge of the anatomical structure of the skin is important for a better understanding of the barrier function, penetration of substances, absorption of chemicals and immunological aspects of skin in response to external factors. The chapter will provide information about the function, uses and the different types of barrier creams available in the industry and the advantages and disadvantages of barrier creams to the skin barrier. Previous studies involving barrier creams will be discussed. The three parameters used in this study to measure skin barrier function are stratum corneum hydration, TEWL and skin surface pH. The endogenous, exogenous and environmental factors that can influence these parameters and measurements thereof will also be discussed.

2.1 Barrier creams

2.1.1 Function

Barrier creams are also known as protective skin creams, shielding lotions and pre-work creams, gels or lotions. Barrier creams are topically applied and function as a non–permeable barrier on the skin surface. Barrier creams are used as a measure to prevent exposed skin from penetration and absorption of hazardous substances in the workplace, and are intended to be applied before work and regularly during a work day (Schliemann *et al.,* 2012).

Barrier creams form a physical layer (barrier) on top of the skin surface preventing penetration of hazardous substances and reinforcing the natural barrier of the skin. Barrier creams act as a defence to prevent penetration of irritants into the epidermis and preventing cutaneous damage. In the industry barrier creams are used for the prevention of allergic contact dermatitis and irritant contact dermatitis. The formulation of barrier creams to prevent allergic contact dermatitis, involves decreasing of allergen availability to epidermal antigen presenting cells namely Langerhans cells, by blocking absorption of the allergen (Alvarez *et al.,* 2001).

When a barrier cream is applied to the skin surface it functions as an artificial barrier; the barrier cream gets absorbed by the superficial layer of the epidermis and is not removed when conventional hand washing occurs (Madison, 2003). The barrier function of the skin is related to the lipid and water content of the stratum corneum, thus when damage or dehydration to the skin occurs, barrier function will become impaired (Alvarez *et al.,* 2001). Barrier creams help by preventing transepidermal water loss (TEWL) and the loss of lipids from exposure to chemical irritants and frequent hand washing (McCormick *et al.,* 2000).

2.1.2 Uses of barrier creams

It is important to choose the correct barrier cream for a specific exposure as studies have shown the incorrect barrier cream can aggravate a skin condition (Wulfhorst *et al.,* 2011). It is important to note that barrier creams can also differ for the type of application required such as: medical application for when a diaper rash occurs, industrial application when protecting a worker and sporting application for wrestlers (Hand and Wroble, 1999). For the purpose of this study only industrial types of barrier creams and their functions will be discussed. There are three types of barrier creams, namely water repellent, oil repellent and silicone repellent used in the industry which will be summarised in Table 1 (Schalock and Zug, 2007).

Table 1: The different types of barrier creams (Schalock and Zug, 2007)

TYPES	WATER-REPELLENT	OIL-REPELLENT	SILICONE-REPELLENT
USES	Wet-work, prevention to water-soluble irritants.	Protects against oils, greases, oil-soluble substances.	Multi-purpose, general protection from water soluble and organic compounds. Dirt and grime.
INDUSTRY	Hospital employees Clinics Hairdressers Catering facilities Machinist	Engineering Factories Welding Manufacturing plants	Everyday use.

2.1.3 Barrier creams used

For this study the following three barrier creams were selected namely Reinol Skingard™, Gloves In A Bottle™ and Travabon™. Travabon™ and Reinol Skingard™ are currently in use in the industry whereas Gloves In A Bottle™ is a new type of barrier cream on the market and is widely advertised.

Water repellent hydrophobic barrier creams contain ingredients such as: stearic acid, dimethicone (film forming agent) and dimethodioxane, while oil repellent lipophobic barrier creams contain ingredients such as: propylene glycol, glycerine (humectant) and sorbitol (Alvarez *et al.,* 2001).

Most barrier creams contain tannery substances, talcum, perfluoropolyethers (PFPEs), chelating agents, and organoclays, zinc oxide, tannin and petroleum which can contribute to the barrier cream's protecting effect. Zinc oxide is described as having a shielding effect (Alvarez *et al.,* 2001) and is also widely used in sunscreens. In a study done by Ghadially *et al.* (1992) it was shown that petrolatum on hairless mice penetrates into the intercellular spaces of the stratum corneum providing a barrier on the skin. Barrier creams containing chelating agents such as diethylentriaminepenta-acetic acid are reported to prevent contact allergic reactions to metals on the skin (Kütting and Drexler, 2003). Chelating agent's pharmaceutical formula increases the efficacy of creams by complexing metal ions which conceals it from the immune system and reduces the penetration of metal ions into the epidermis (Smolik *et al.,* 2008).

There are thirty three different brands of manufactured barrier creams internationally from South Africa, USA, UK, Australia and India of which eighteen are available in South Africa. Uses differ between clinics, hospitals, food production, offices, workshops, factories and mines, for skin exposed to acids, alkalis, resins, chemicals, dust, dyes, varnishes, oils, water, detergents, paints and petrol.

2.1.4 Previous studies on the use of barrier creams

To date, different test models to evaluate the efficiency of skin protection products are used. Some of the models analyse, for example, the penetration and binding properties of dyes to the stratum corneum to judge the protective characteristics of barrier creams. Others studies used bioengineering techniques (like TEWL) to evaluate the influence of skin protective products on the irritant reaction of the skin *in vivo.* Bioengineering methods and clinical scoring seem to be most promising to monitor the complex interaction between irritant, skin protective product and human skin (Fluhr *et al.,* 2007; zur Mühlen *et al.,* 2007).

2.1.5 Advantages of barrier creams

According to Wulfhorst *et al.* (2011), barrier creams are the only preventative measure in certain occupations with a requirement for a sense of touch, finger mobility and when working with rotating machines where gloves can be ripped. When preventing workers from allergic contact dermatitis and irritant contact dermatitis, barrier creams can be a useful measure (Alvarez *et al.,* 2001). Barrier creams are effective when removing sticky oils, greases and resins from the skin, which decreases the need to wash the skin with potentially irritating abrasives and waterless cleansers (Kütting and Drexler, 2003). Where rotating devices are used barrier creams are the only option due to work safety and can also be used to reduce unnecessarily long glove usage (Schliemann, 2007). When a barrier cream is combined with an after-work cream/product the barrier cream is more beneficial to the worker (Schliemann *et al.,* 2012). Some workers prefer wearing barrier creams instead of gloves claiming they do not want their hands to be 'sealed' inside a glove (Zhai and Maibach, 2007). Long-term wearing of gloves can cause rubber glove allergy, therefore, the use of barrier creams can help to reduce long term glove use (Schliemann, 2007).

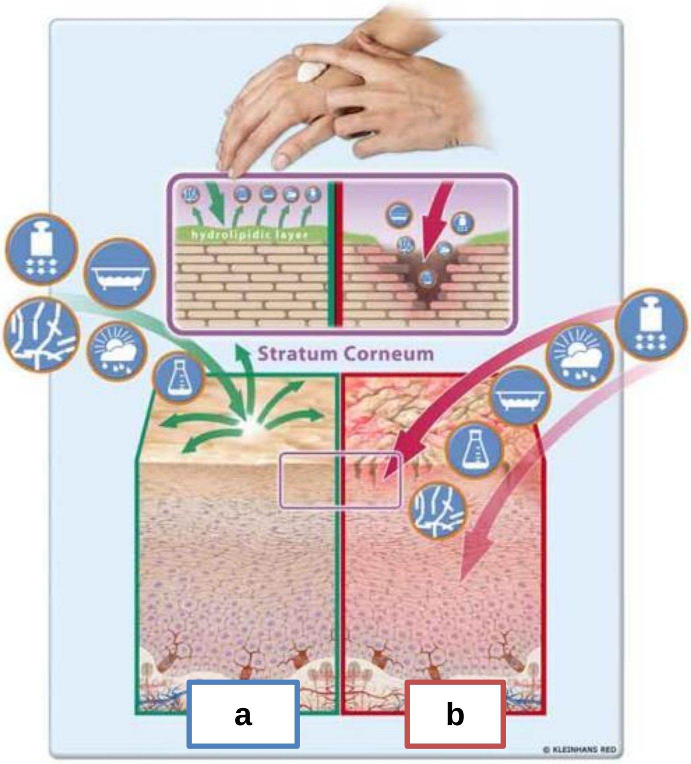

Figure 1: Schematic illustration of a stratum corneum that is protected by a barrier cream, a: the stratum corneum is protected when using a barrier cream, b: is an unprotected stratum corneum (BASF, 2007).

2.1.6 Disadvantages of barrier creams

A study by Alvarez *et al.* (2001) has shown that certain irritants may become trapped on the skin while using barrier creams. Because of the ingredients of barrier creams such as preservatives, fragrances, propylene glycol, urea and emulsifiers; barrier creams can also cause sensitisation (Alvarez *et al.,* 2001; Uter *et al.,* 2001; Schliemann, 2007). According to Schalock and Zug (2007), barrier creams are potentially useful in research when investigating irritant contact dermatitis, although barrier creams do not seem to be in general use in the workplace. The main disadvantage of barrier creams is the frequency and proper application that is required (Alvarez *et al.,* 2001). There is no exact guideline to the correct amount that should be used on the skin surface each day. Manufactures use terms like pea size amount/spoon-full when describing the amount of barrier cream. In a recent study by Schliemann *et al.* (2012) investigating the doses per unit area of barrier creams applied, they stated that the layer of thickness will be different when looking at sex, occupation, and preceding or prevalent hand dermatitis of test subjects. The frequency of applying the barrier cream is also varied because different manufacturers state different quantities for example; every 4 hours, regularly during the day, or after each break. Studies claim barrier creams also gives a false sense of protection to workers (Alvarez *et al.,* 2001). In a study done by Allmers (2001) it was shown that healthcare workers applied barrier creams before wearing natural rubber latex gloves. This can increase allergic reaction on the skin because skin barrier creams can promote the uptake of allergens from gloves. Depending on the hypersensitivity of a worker, the reaction will be different (Allmers, 2001).

2.2 Skin anatomy and structure

The human skin consists of two regions: an outer epidermis and an underlying dermis of connective tissue and blood vessels (McGrath *et al.,* 2004; Bouwstra and Ponec, 2006). The epidermis-dermis junction is undulating and ridges known as rete-ridges of the epidermis project into the dermis. This junction provides mechanical support while also acting as a partial barrier against the exchange of cells and large molecules (McGrath *et al.,* 2004). The dermis provides nutritional support for the avascular epidermis (Kielhorn, 2006). The dermis varies in thickness according to the body region. It ranges from 0.3 mm on the eyelids to 3 mm on the palms of the hands and soles of the feet (Igarashi *et al.,* 2005). Hair follicles, eccrine glands and apocrine sweat glands arise into the epidermis and are all located in the dermis (Kielhorn, 2006). The dermis provides a supporting matrix in which polysaccharides and proteins are linked producing macromolecules with a high capacity to retain water. This supporting matrix mainly consists of two types of protein fibres namely collagen for a great tensile strength, and elastin. Collagen fibres form vast and tough networks providing the dermis with strength, tension and elasticity. Elastin fibres provide skin with elasticity and resilience, and play an important role in providing structural support to the dermis. The dermis consists of fibroblast cells, mast cells and macrophage cells which also originate in the dermis (Gawkrodger, 2002; Kielhorn, 2006). The dermis has a rich amount of blood supply although none of the blood vessels pass through the dermal-epidermal junction (McGrath *et al.,* 2004). The superficial layer of the epidermis consists of stratified squamous epithelial cells mainly composed of keratinocytes which synthesise the protein keratin (Gawkrodger, 2002; McGrath *et al.,* 2004). Keratin fibres protect the inner side of skin from the external environment and they contribute to moisture-retention in skin by holding water. The keratinocytes are connected by protein bridges called desmosomes and undergo terminal differentiation (Gawkrodger, 2002; McGrath *et al.,* 2004).

There are several cell layers in the epidermis, namely melanocytes providing melanin to keratinocytes, Langerhans cells which have an immunologic function and Merkel cells associated with cutaneous nerves. The four morphological layers of the epidermis are formed by transit or epidermal turnover of keratinocytes. The layers are the stratum germinativum (stratum basale), stratum spinosum, stratum granulosum and stratum corneum. Together the stratum basale and stratum spinosum are referred to as the Malphighian layer. Located above the basale cell layer, keratinocytes are found, forming the prickle layer namely the stratum spinosum. The stratum granulosum layer is above the stratum spinosum. The cytoplasm of cells in the upper spinous layer and granular cell layer contain small granules, known as lamellar granules/bodies, membrane-coating granules and Odland bodies. These cells migrate from the spinous layer to the peripheral layer of the cells to enter the granuler cell layer (Gawkrodger, 2002; McGrath *et al.,* 2004). Lipid content of the lamellar granules/bodies are secreted into the intercellular spaces and are important for barrier function and intercellular cohesion of the stratum corneum (McGrath *et al.,* 2004; Bouwstra and Ponec, 2006). The lamellar granules/bodies play an important role in the stratum corneum formation and serve as carriers of stratum corneum barrier lipids (Bouwstra and Ponec, 2006). The skin barrier function is dependent on the composition and structure of the stratum corneum (Kezic *et al.,* 2009).

The corneocytes of the stratum corneum are formed during differentiation of keratinocytes through interacting with the matrix protein, filaggrin. Filaggrin plays a role in skin barrier homeostasis and compresses keratin filaments into tight bundles. This leads to the collapse of the corneocyte cells into the flattened shape (Bouwstra and Ponec, 2006; Proksch *et al.,* 2006). Corneocytes are a-nucleated, flattened cells surrounded by a cornified cell envelope within the plasma membrane formed by involucrin, a cross linked protein (Bouwstra and Ponec, 2006; Proksch *et al.,* 2008; Schaefer *et al.,* 2011). The corneocytes are tightly packed and attached to each other through corneodesmosomes, embedded in a lipid enriched intercellular matrix with a multilamellar structure (Tagami, 2008). Desquamation is the process where the outermost cells are degraded from the skin surface. This process is necessary because the integrity of the stratum corneum is important to the protecting function when serving as a physical barrier (McGrath *et al.,* 2004; Edwards, 2006).

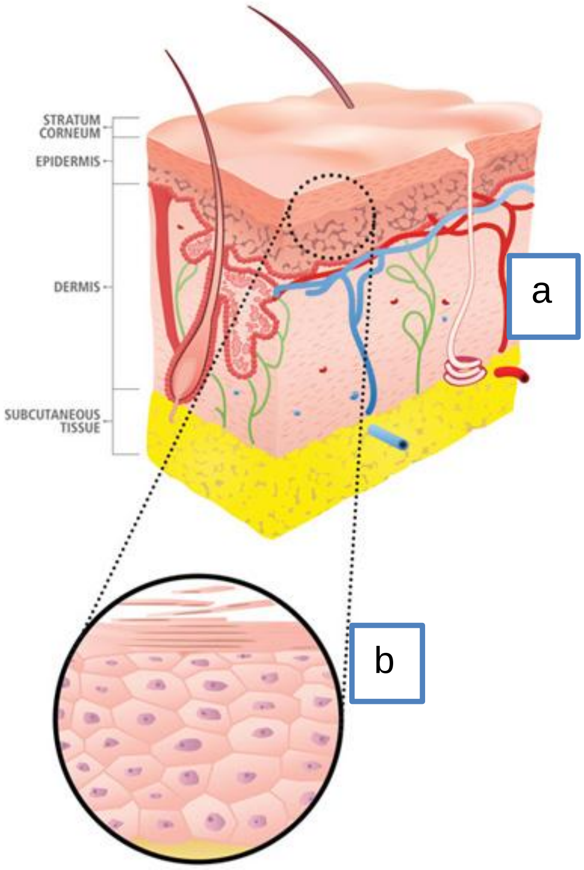

Figure 2: a: Schematic illustration of the skin layers, b: the brick-and-mortar composition of the stratum corneum (EDC, 2008).

2.3 Skin barrier function

The skin forms an effective physical barrier between human skin and the outside environment protecting the body against penetration of harmful substances and preventing water loss (Bouwstra and Ponec, 2006; Proksch *et al.,* 2008). The main protective barrier of the skin is located in the outermost layer of the skin, the stratum corneum (Bouwstra and Ponec, 2006). The stratum corneum is involved in the regulation of water vapour released from the skin into the atmosphere and this is known as TEWL (Proksch *et al.,* 2008). The stratum corneum is a thin (8 - 20 µm) layer of corneocytes. It is described as a highly differentiated structure for the diffusion of compounds across the skin (Schaefer *et al.,* 2011). The physical description of the stratum corneum is characterised as "bricks" referring to the cornified cells embedded in a "mortar" of intracellular lipids (Jungersted *et al.,* 2008), therefore, referring to the organisation as a "brick-and mortar" composition.

These lipids of the stratum corneum have a unique composition and are differentiated from lipids in the biological membrane (Feingold, 2007). The lipids are derived from lamellar bodies and are arranged on the cell surface. The three primary lipids that are integrated in the stratum corneum are ceramides, free fatty acids and cholesterols (Jungersted *et al.,* 2008; Proksch *et al.,* 2008). Fatty acids are required for structure and permeability of the barrier function of the stratum corneum and cholesterol plays a role in corneocyte desquamation (Feingold, 2007). When there is a change in lipid composition and cell structure during terminal differentiation, a tightly packed structure in the stratum corneum is formed (Bouwstra and Ponec, 2006). The lateral packaging is very important for barrier function of the stratum corneum (Bouwstra and Ponec, 2006).

When the skin barrier becomes disrupted by mechanical forces, solvents or detergents, an immediate homeostatic repair response takes place leading to a recovery of the permeability of barrier function. The contents of the lamellar bodies of the outer stratum granulosum are secreted. The newly formed lamellar bodies will appear in the stratum granulosum cells and secretion will continue until the permeability of the barrier function is returned to normal (Feingold, 2007).

2.4 Skin barrier parameters

The three parameters used in this study to measure skin barrier function are stratum corneum hydration, TEWL and skin surface pH.

2.4.1 Stratum corneum hydration

The hydration state of the stratum corneum provides important information on the biophysical properties of the skin and the function of the skin barrier (Alanen *et al.,* 2004). Diffusion of water through the stratum corneum is a passive process (Tagami, 2006). An important function of the water in the stratum corneum is to participate in hydrolytic enzymatic processes required for desquamation (Verdier-Sévrain and Bonté, 2007).

The skins ability to hold water is primarily related to the stratum corneum, which plays the role of a barrier to water loss (Verdier-Sévrain and Bonté, 2007). The skin will feel soft and flexible when there is an adequate amount of water in the stratum corneum and this appearance represents an intact skin barrier (Alanen *et al.,* 2004). The water content of the stratum corneum will affect barrier permeability and mechanical properties, along with the regulation of hydrolytic enzymes that play a role in corneocyte desquamation. If the stratum corneum fails to retain water, dryness of the skin and impaired function will occur (Darlenski *et al.,* 2009).

Water concentration within the stratum corneum is the highest in the lower layer of the stratum corneum and lowest in the uppermost layer of the stratum corneum (Tagami, 2006). If the stratum corneum water content decreases below a critical level, enzymatic function for desquamation becomes impaired. Corneocytes will accumulate on the cutaneous skin surface causing the skin to appear dry and flaky. Within corneocytes are hydroscopic molecules that maintain hydration of corneocytes and keep the stratum corneum hydrated. Most of the water found in the stratum corneum is located inside the corneocytes (Verdier-Sévrain and Bonté, 2007).

The stratum corneum hydration state is also influenced by ambient relative humidity because the stratum corneum is exposed to the atmosphere (Tagami, 2006).

Table 2: Interpretation of hydration index measurements (Courage and Khazaka, 2009)

Hydration index	Skin condition
< 30	Very dry skin
35 - 45	Dry skin
> 45	Sufficiently moisturised skin condition

2.4.2 Transepidermal water loss (TEWL)

Transepidermal water loss is an important measure when investigating skin barrier function. TEWL is the outward diffusion of condensed water through the stratum corneum of the epidermis into the atmosphere (Imhof *et al.,* 2009). The SI unit g m^{-2} h^{-1} represents TEWL and water vapour flux density (Levin and Maibach, 2005; Imhof *et al.,* 2009).

Total water vapour loss can be determined by measuring TEWL. In case of sweating the sweat glands produce large amounts of water, which evaporates, and by the same principle, this diffusion of water vapour by sweating can be quantified by measuring TEWL (Harmsze *et al.,* 2008). It should be noted that TEWL only reflects stratum corneum barrier function for water when there is no sweat gland activity (Tupker and Pinnagoda, 2006). TEWL is an effective skin barrier measure because the TEWL water has to diffuse through the skin barrier, from a high concentration inside the body to a low concentration at the skin surface (Imhof *et al.,* 2009).

TEWL values are known to vary with anatomical sites and are influenced by eccrine sweat gland activity. The highest TEWL values occur on the palm, soles of the feet and the forehead. (Oestmann *et al.,* 1993; Kleesz *et al.,* 2012). In a study by Levin and Maibach (2005), they reported that TEWL measurement can also be influenced by skin surface temperature, ambient air humidity and ambient air temperature. When there is an increase in TEWL it is a reflection of a diseased and damaged skin and by association an impaired skin barrier (Levin and Maibach, 2005).

Table 3: Interpretation of TEWL index measurements (Delfin, 2010)

TEWL index ($g\ m^{-2}\ h^{-1}$)	**Interpretation**
0 – 8	Very healthy skin barrier condition
8 - 14	Healthy skin barrier condition
14 - 20	Normal skin barrier condition
20 - 24	Strained skin barrier condition
> 25	Critical skin barrier condition (possible damage)

2.4.3 Skin surface pH

The skin surface pH is an important parameter of epidermal permeability, barrier homeostasis and can affect desquamation (Rippke *et al.,* 2004; Fluhr *et al.,* 2006; Darlenski *et al.,* 2009).

An optimal stratum corneum pH is necessary for the activation of lipid hydrolase in the cornified layer, and is required for the post secretory processing of lamellar bodies. The lamellar bodies are important for the formation of the skin barrier (Fluhr *et al.,* 2006). Studies show that the pH of the skin has a sharp gradient across the stratum corneum and is important when controlling enzymatic activities and skin renewal (Schmid-Wendtner and Korting, 2006). An acidic environment of the skin is important for the regulation of the enzyme activities in the stratum corneum (Feingold, 2007). The upper stratum corneum pH values are lower than the physiological pH. The cutaneous pH gradient within the stratum corneum rises up into the epidermis, reaching the body's internal pH at the level of the stratum granulosum (Fluhr *et al.,* 2006).

When there is an increase in the stratum corneum pH, protease activity will be stimulated and corneocyte desquamation will increase (Feingold, 2007). In a study by Yosipovitch *et al.* (1998) it was stated that a high pH value will correlate with a high TEWL value. Cutaneous inflammatory disorders are associated with increased stratum corneum pH and can affect enzyme activity in the stratum corneum, decreasing barrier permeability and stratum corneum cohesion (Feingold, 2007).

Table 4: Interpretation of pH index measurements (Courage and Khazaka, 2009)

pH-value on skin surface	<3.5	3.8	4.0	4.3	4.5	5.0	5.3	5.5	5.7	5.9	6.2	6.5	>6.5
Women	+ acidic range -				Normal				- High skin pH value +				
Men	+ acidic range -			Normal					- High skin pH value +				

There is variation in skin barrier function and a variety of factors that can influence the skin barrier function, therefore, the most important factors will be discussed briefly.

2.5 Factors influencing skin barrier function

2.5.1 Endogenous factors influencing skin barrier function

Age

The skin undergoes morphologic and physiologic changes when growing older. The aging of the skin is influenced by environmental and hormonal factors. The normal process of skin aging involves gradual thinning, atrophy, dryness, skin fragility and finally wrinkling. These structural alterations are due to atrophy of collagen (Shah and Maibach, 2001). An increase in age leads to a decrease in stratum corneum thickness (Jacobi, 2005). Throughout the aging process, stratum corneum hydration and TEWL decreases. The decrease in TEWL is evident at the age of 60 years (Farinelli and Berardesca, 2006). Aging elevates skin surface pH (Fluhr *et al.,* 2006) and an increase in the pH of the stratum corneum will influence the lipid composition of the skin (Jungersted *et al.,* 2008).

Gender

A study by Jacobi (2005) found conflicting results regarding gender differences and skin composition. Females have a more acidic pH skin condition with no differences in TEWL and hydration between males and females (Chilcott and Farrar, 2000; Fluhr *et al.,* 2006). The more acidic skin of females can be because of hormonal differences that affect sebum secretion and perspiration. There is greater occurrence of skin irritability in females than males, therefore, a female's skin is more prone to irritation than the skin of males. Variations in skin reactivity occur during the menstrual cycle, leading to skin changes in extensibility and an increase in proneness to this will develop a strong irritant reaction during menstrual phase (Farinelli and Berardesca, 2006).

Anatomical area

The skin barrier efficiency is not uniform over the body. The anatomical differences vary because of stratum corneum thickness, the distribution of appendages and melanocytes, and variation of the structure of the dermis and blood supply (Farinelli and Berardesca, 2006). The differentiation of the stratum corneum of the palms of the hands and the soles of the feet are unlike the rest of the skin. The palms and soles are impermeable whereas the scrotum is permeable and also has the thinnest stratum corneum layer (Farinelli and Berardesca, 2006). There are differences in the pH according to skin sites. In skin flexure areas such as the forehead, palms, wrist, soles of the feet and toes with a high sweat secretion the pH value will be between 5 – 7 (Öhman, 2006).

TEWL increases with the thickness of the stratum corneum especially on the palms and soles. The regional variation in TEWL and permeability is due to the regional variation of the total lipid content of the stratum corneum (Farinelli and Berardesca, 2006). Stratum corneum hydration differs between anatomical areas, where these values are high in the forearm, palm and hand and lower in die abdomen, thigh and lower leg (Barel and Clarys, 2006; Farinelli and Berardesca, 2006).

Ethnicity

Pigmentation is the most obvious difference in skin characteristics between different racial groups. Stratum corneum thickness is equal in African and Caucasian skin, although African skin has an increased number of corneocyte layers and the stratum corneum lipid content is higher in African skin (Farinelli and Berardesca, 2006; Rawlings, 2006). Stratum corneum layers in black skin are more compact because of greater intercellular cohesion whereas Caucasian skin has less corneocyte cell layers (Farinelli and Berardesca, 2006; Fluhr *et al.,* 2008). It has been reported that stratum corneum function is stronger in African skin (Rawlings, 2006).

There is no difference in corneocyte size although the desquamation rate in African skin is higher due to lower intercellular ceramide levels (Rawlings, 2006). Studies reported a difference in stratum corneum hydration in ethnic groups, while other studies reported no difference (Berardesca and Maibach, 2003; Fluhr *et al.,* 2008). Berardesca and Maibach (2003) stated that *in vitro* measurements of TEWL were higher for African skin when compared to Caucasian skin, and a higher *in vivo* TEWL was measured for African skin while other results indicated no ethnic difference in TEWL. The skin's lipids play a role in modulating the relationship between stratum corneum water content and TEWL. Farinelli and Berardesca, (2006) stated that Caucasian skin is more susceptible to irritants than African skin.

Different races showed differences in TEWL values in the volar and dorsal forearms. It would be expected that the higher the stratum corneum water content the higher the TEWL value will be which can be explained in terms of difference in intercellular cohesion, lipid composition and hair distribution. When examining skin pH, African skin has a lower pH than Caucasian skin (Fluhr *et al.,* 2008). Also different racial groups will have different skin responses to topical and environmental agents (Farinelli and Berardesca, 2006).

2.5.2 Endogenous factors influencing skin barrier function

Skin health

Allergic contact dermatitis and irritant contact dermatitis are the most common occupational skin diseases and are linked to mechanical stress and contact with substances which damage the skin barrier (zur Mühlen *et al.,* 2007). When a person has irritant contact dermatitis or allergic contact dermatitis the skin barrier will be disrupted (Proksch *et al.,* 2008). Inflammatory skin diseases, for example, atopic dermatitis and psoriasis have been the most studied in terms of epidermal barrier function (Madison, 2003). When swelling and redness occur on the skin the barrier function of the stratum corneum will partially be destroyed and this will lead to a lower water content of the stratum corneum layer (Barel and Clarys, 2006). Change in the epidermal differentiation and lipid composition leads to a disrupted barrier which can lead to entry of allergens, inflammation and atopic dermatitis (Proksch *et al.,* 2008). Inflammatory skin disorders will lead to an increased stratum corneum pH and can affect enzyme activity in the stratum corneum, causing a decrease in permeability barrier function and stratum corneum integrity (Feingold, 2007).

Season

The skin is exposed to all elements of the external environment including temperature changes, relative humidity and seasonal variations. The skin serves as a thermoregulation organ, where the rate of blood flow and sweating controls the body’s temperature (Goh, 2006). High temperature and high values of relative humidity during the summer will result in higher hydration values (Barel and Clarys, 2006). Skin surface temperature differences can contribute to the differences in TEWL (Rawlings, 2006).

An increase in environmental temperature will increase blood flow, stimulating sweat glands to increase sweat secretion. An increase in sweat will lead to a decreased skin pH and an increase in hydration of the stratum corneum, thus enhancing penetration of chemical agents on the skin (Goh, 2006). High humidity prevents skin surface sweat from evaporation leading to an increase in hydration and low humidity will lead to a dry skin appearance (Goh, 2006). A cold environment is known to cause irritant skin changes, for example, dry and scaly skin. Winter leads to decreases in epidermal hydration causing epidermal barrier function to become impaired (Uter *et al.,* 1998). Dry skin will increase TEWL and irritability (Rippke *et al.,* 2004).

2.6 Factors influencing skin barrier measurement

The factors that can influence these measurements will be discussed henceforth.

2.6.1 Exogenous factors influencing skin barrier measurement

Smoking

A study by Muizzuddin (1997) found that when comparing an active group of smokers to a non-smoking group, the active smokers had poor barrier function, wrinkles and dry skin condition. The non-smoking group had a low TEWL whereas the active smoking group had a high TEWL, along with low stratum corneum hydration and dry, flaky skin (Muizzuddin, 1997). Low hydration causes impairment of the epidermal barrier. Dry skin will, therefore, result in a decrease in hydration values (Uter *et al.,* 2001; Barel and Clarys, 2006).

Diet

The relationship between nutrients and skin is evident from the incidence of skin problems as a result of nutritional deficiencies. Food consumption especially fat, sweet and spicy food can influence skin condition (Boelsma *et al.,* 2003). Spicy food for example ginger and red chillies can cause the skin to become irritable and sensitive and also lead to an increase in skin temperature (Escalas-Taberner *et al.,* 2011). A high skin temperature can lead to sweating of the skin causing it difficult to conduct hydration measurements, leading to results that are much higher than expected (Barel and Clarys, 2006). When spicy food increases skin temperature there will be an increase in hydration of the stratum corneum of the skin which can lead to the increase in penetration of harmful substances (Goh, 2006).

Cosmetic products

Moisturisers applied to the skin will increase the hydration state of the skin surface and will improve barrier function and give a false sense of hydration when measuring hydration and TEWL (Tagami, 2006). The pH of the skin plays an important role in skin barrier homeostasis, therefore, using cosmetic products that can increase stratum corneum pH can lead to cutaneous damage and inflammation (Rippke *et al.,* 2004). Inflammation can disrupt the skin barrier which could influence stratum corneum hydration, TEWL and skin pH values. Certain soaps with a high alkaline content can lead to the skins acidic mantel increasing in alkalinity. Creams containing oil and wax can prevent, to some extent, evaporation of epidermal water loss (Kampf and Ennen, 2006). Frequently applied cosmetic products along with an irritation on the skin can cause damage to the skin barrier integrity (Bronaugh, 2010).

Alcohol

The consumption of alcohol leads to dilation of facial blood vessels and an increase in blood flow leading to sweat production. Alcohol can lead to dehydration of the body, skin irritability and dehydration of the skin (Escalas-Taberner *et al.,* 2011). A dehydrated skin's appearance is dry and unhealthy. Dry skin will cause impairment of the skin barrier, making the skin more permeable. An impaired skin barrier will increase allergen penetration into the skin (Tagami, 2006; Proksch *et al.,* 2008). When measuring hydration values lower than expected will result, changes in pH can occur indicating an abnormality in skin barrier function (Barel and Clarys 2006; Schmid-Wendtner and Korting, 2006).

2.6.2 Environmental factors and seasonal variations

Environmental factors such as temperature, relative humidity along with seasonal variations can affect skin barrier measurements of stratum corneum hydration, TEWL and skin surface pH. An increased skin temperature will increase sweating causing increased stratum corneum hydration which could lead to false hydration readings (Goh, 2006).

The skin serves as a physical barrier to the environment, providing protection against micro-organisms, ultraviolet radiation, toxic agents and mechanical insults. Protecting the worker against harmful skin conditions can be a large task. The right type of barrier cream can be used in the workplace to achieve hand protection. There is a wide variety of barrier creams available in the industry. Controversial studies about barrier cream function and effectiveness still exist making it necessary to determine the effects on the skin barrier function. Studies regarding ethnicity in skin function are also a conflicting matter. Therefore, this study investigated the effects of three different barrier creams on the skin barrier function in terms of stratum corneum hydration, TEWL and skin surface pH and also comparing the effects of barrier creams between Caucasian and African skin.

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The influence of different types of barrier creams on skin barrier function

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Word count: 6089

Abstract:

Barrier creams are used in the industry as a protective measure to prevent the penetration of harmful substances through the skin surface. Controversy exists about the frequency and adequate application of barrier creams on the skin and their effect on skin barrier function. Studies have reported differences in stratum corneum hydration and transepidermal water loss while others reported none. Numerous studies have reported skin surface pH differs significantly between Caucasian and African subjects. **Aim:** The main aim of this study was to investigate the effects and the possibility of disadvantages of three different types of barrier creams on the skin barrier function. Secondly to compare different racial skin types (African skin to Caucasian skin) and finally to compare the effect of the three different barrier creams on four different anatomical areas. **Method:** The thirty eight non-smoking male test subjects which consisted of nineteen African and nineteen Caucasian test subjects took part in this study to test the effects of three different types of barrier creams used in the industry, on their arms and hands. The study took place in a controlled laboratory environment. Stratum corneum hydration, TEWL and pH of the skin surface were the three parameters of skin barrier function that were measured. **Results:** Gloves In A Bottle™ increased stratum corneum hydration and skin surface pH, had no effect on TEWL, whereas Reinol™ increased stratum corneum hydration and decreased TEWL with no effects on pH. Travabon™ decreased TEWL and stratum corneum hydration and had no effect on skin surface pH.

Conclusion: Barrier creams are beneficial in the workplace, although it should be taken into consideration that different ethnicities react differently to barrier creams in different workplace situations.

Keywords: barrier cream, skin barrier function, stratum corneum hydration, TEWL, skin surface pH, ethnic differences.

Introduction

Studies regarding the harmful and beneficial effects of barrier creams are controversial (Kütting and Drexler, 2003). In industries such as healthcare settings, metal industry, food, hairdressing and wet-work a compromised skin barrier and damaged skin is seen regularly, causing hand dermatitis which is one of the most common occupational diseases (Bauer *et al.,* 2007).

Barrier creams serve as protective creams that are topically applied to the skin surface. Barrier creams are a recommended precaution and measure, used in the industry to prevent occupational contact dermatitis and penetration of harmful substances (Alvarez *et al.,* 2001). When a barrier cream is applied to the skin it forms an impermeable layer to prevent hazardous substances from entering into the skin (Wigger-Alberti and Elsner, 2000). Barrier creams can alter the penetration of substances into the skin by an interaction between the barrier cream and substance (Fluhr *et al.,* 2007). Barrier creams may act in three different levels on the epidermis, these being an immediate effect by adding a lipid mixture to the skin surface (occlusion); an intermediate effect by adding a lipid mixture to the intercellular spaces and a delayed effect by providing lipids to the epidermal cells which could restore the natural barrier function of the skin (Christopher and Galea, 2008). Barrier creams can exert an occlusive effect on the skin which can influence the stratum corneum hydration state in long term applications (Fluhr *et al.,* 2007).

It is very important to choose the correct type of barrier cream for specific exposures in different workplace settings. There are three types of barrier creams namely water repellent, oil repellent and silicone repellent used in the industry. Where rotating devices or machinery is used, barrier creams are more effective than gloves which can be caught in the machinery or ripped (Wulfhorst *et al.,* 2011). Barrier creams can also be used when protecting workers from allergic contact dermatitis and irritant dermatitis (Alvarez *et al.,* 2001; Wulfhorst *et al.,* 2011). There are no exact guidelines that exist to describe the correct amount of barrier cream that should be applied on the skin for protection. Manufacturers only use terms like a spoon-full when describing the amount of barrier cream. Barrier creams can only be beneficial when applied frequently and correctly.

The ingredients of barrier cream bases contain various fragrances, preservatives, emulsifiers, and emollients, which could cause or induce sensitisation on the skin (Wigger-Alberti and Elsner, 2000). Emollients are designed to increase the water content indirectly by creating an occlusive film on the skin surface, which traps the water in the upper layers of the stratum corneum. When water becomes trapped in the upper layers of the stratum corneum the hydration state will increase (Fluhr *et al.,* 2007). The interaction of the skin, the barrier cream formulation and irritant is complex and still needs further investigation (Wulfhorst *et al.,* 2011).

The stratum corneum is part of in the epidermis and is a highly organised differentiated structure that determines the diffusion of compounds across the skin (Schaefer *et al.,* 2001). Measurable parameters namely stratum corneum hydration, transepidermal water loss and skin surface pH are indications of skin barrier function. The factors that can influence skin barrier function are age, gender, anatomical area, skin health, environmental factors and ethnicity (Denda, 2000; Rawlings *et al.,* 2008; Denda, 2012). Studies referring to ethnic groups are regarded as controversial when referring to barrier function because of the structural and biophysical differences (Rawlings, 2006).

The stratum corneum hydration state provides important information on the biophysical properties of the skin and the function of the skin barrier (Alanen *et al.,* 2004). A normal hydration state represents an intact skin barrier, while a dry skin state represents an impaired barrier function and skin dryness (Alanen *et al.,* 2004; Darlenski *et al.,* 2009). Table 1 indicates the range and interpretation of stratum corneum hydration values.

Table 1: Interpretation of skin hydration measurements (Courage and Khazaka, 2009)

Hydration index	**Skin condition**
< 30	Very dry skin
35 - 45	Dry skin
> 45	Sufficiently moisturised skin condition

TEWL is the outward diffusion of condensed water through the stratum corneum of the epidermis into the atmosphere, although it should be noted that TEWL only reflects stratum corneum barrier function for water vapour when there is no sweat gland activity (Tupker and Pinnagoda, 2006; Imhof *et al.,* 2009). Transepidermal water loss is an important measure when investigating skin barrier function because water diffuses through the skin barrier, from a high concentration inside the body to a low concentration on the skin surface (Imhof *et al.,* 2009). When the skin barrier is disrupted or damaged there will be a high TEWL value which indicates critical skin barrier function (Levin and Maibach, 2005). Table 2 indicates the range and interpretation of TEWL values.

Table 2: Interpretation of TEWL measurements (Delfin, 2010)

TEWL index ($g\ m^{-2}\ h^{-1}$)	**Interpretation**
0 – 8	Very healthy skin barrier condition
8 - 14	Healthy skin barrier condition
14 - 20	Normal skin barrier condition
20 - 24	Strained skin barrier condition
> 25	Critical skin barrier condition (possible damage)

Skin surface pH is an important parameter of epidermal permeability, and an acidic environment is important for the regulation of enzyme activities in the stratum corneum (Rippke *et al.,* 2004; Fluhr *et al.,* 2006; Feingold, 2007; Darlenski *et al.,* 2009). An increase in stratum corneum pH can affect enzyme activity in the stratum corneum which will cause a decrease in permeability, barrier function, integrity and stratum corneum cohesion (Feingold, 2007). Table 3 indicates the range and interpretation of skin pH values.

Table 3: Interpretation of pH measurements (Courage and Khazaka, 2009)

pH-value on skin surface	<3.5	3.8	4.0	4.3	4.5	5.0	5.3	5.5	5.7	5.9	6.2	6.5	>6.5
Women	+ acidic range -				Normal				- High skin pH value +				
Men	+ acidic range -			Normal					- High skin pH value +				

Methods

Study design:

To determine the effect of barrier creams on the skin barrier function, the stratum corneum hydration, transepidermal water loss (TEWL) and skin surface pH were measured. Three types of barrier creams were tested namely Reinol Skingard™, Gloves In A Bottle™ and Travabon™. Travabon™ and Reinol Skingard™ are currently in use in the industry while Gloves In A Bottle™ is a new type of barrier cream distributed in South-Africa and widely advertised. TEWL was measured using a Vapometer (Delfin Technology Ltd. Finland). The Multi probe Adapter system (MPA) (Courage and Khazaka, Germany) was used with a temperature and humidity sensor and with the following probes all from Courage and Khazaka, Germany: a Corneometer (CM 825) measuring skin hydration and a pH-Meter measuring skin surface pH and a Thermometer measuring the skin temperature.

Test subjects:

The study recruited forty test subjects of which two subjects could not finish the study. Thirty eight non-smoking male test subjects between the ages of 20 - 25 years of age took part in this study and each subject was tested using all three types of barrier creams on different days. The 38 test subjects consisted of 19 African test subjects and 19 Caucasian test subjects. All test subjects were asked to sign a letter of informed consent stating that they willingly took part in this study.

The test subjects were asked not to bath or shower on the day of the measurement but rather the day before. The test subjects were asked not to apply any cosmetic formulation 12 hours prior to measurement and wore suitable clothes that ensured that the forearm was uncovered. The test subjects were asked not to consume alcohol 12 hours prior to measurements. The test subjects kept a record of their activities, dietary intake and their washing regimes and were asked not to rub their hands together on the day that the measurements took place.

Acclimatisation:

The room temperature where the measurements were taken was regulated between 20 - 22 °C prior to measuring; and the relative humidity was measured to ensure it was between 40 - 60%. Each test subject acclimated for 20 minutes in the laboratory where the sampling took place. During acclimatisation the Dalgard *et al.* (2003) skin questionnaire along with a checklist were completed under the guidance of the researcher. The questionnaire obtained information about the test subjects' skin health, age, washing habits, smoking habits and health history. The Vapometer, Thermometer, Corneometer and pH meter were acclimated 20 minutes before the start of measurement by the researcher every day according to manufactures guides.

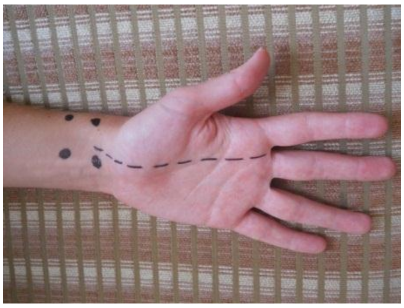
Skin measurement and barrier cream application:

The measurements were repeated on each of the four sampling areas (forearm, wrist, back of hand and palm) with a reasonable time interval between each measurement. Three values were obtained on each of the sampling areas, and the measurement values were averaged for statistical analysis. The precise sampling area where the probes were placed was marked with a pen on the skin taking care not to mark inside the measurement area (Figure 1). After the baseline measurement the barrier cream was applied by the researcher on the test subjects' dominant arm. The long term effects were determined after the baseline measurement in intervals of 2 hours. Directly after each measurement the barrier cream was reapplied.

The barrier cream was applied by the researcher to the test subject's dominant arm and the other unapplied arm was used as the control. Five milliliters of barrier cream was measured with a measuring spoon. The researcher applied the barrier cream on the test subject's dominant arm, starting at the back of the hand, moving to the palm, wrist, and forearm and applying up to the elbow. The researcher took care to apply the barrier cream evenly including the cuticles and between fingers. The barrier cream was massaged into the arm and hand until the whitish layer had disappeared. A paper towel was dabbed onto the skin to ensure proper absorption and to remove any excess barrier cream.

Sampling areas


a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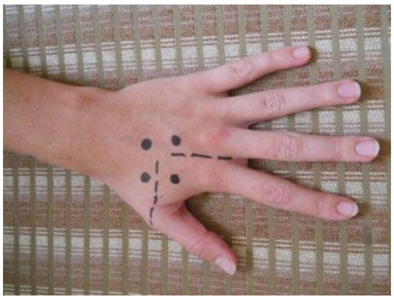
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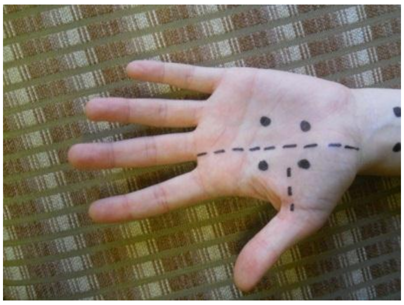
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Figure 1: (a) The forearm's measurement was taken in the middle inside of the forearm. (b) The wrist's measurement was taken in the area between the index and the middle finger, one finger width below the lowest part of the lunate hand bone. (c) The back of the hand's measurement was taken in the area between the index and the middle fingers, and horizontally in line with the base of the thumb. (d) The palm's measurement was taken in the area between the index and the middle fingers, and horizontally in line with the base of the thumb.

Ethical aspects

A letter of application to the Ethical Committee was issued explaining the study and how this study is an extension of a previous study. This study was carried out under the ethical number NWU-00097-10-55 given by the NWU Ethics Committee.

Statistical Analysis

Statistical analysis was performed using Statistica Version 10 (Statsoft, Inc., 2011). Due to the study design of three repeated measurements, statistical analysis was performed on pooled results consisting of averaged data. Percentage differences for every area and every time interval was calculated. Percentage differences between average values of each parameter were calculated using the equation:

$$\%\Delta = \frac{x_a - x_b}{x_b} \times 100$$

Where $\%\Delta$ is the percentage difference, x_a is the experimental value at time intervals, x_b the baseline value. A positive percentage change indicates an increase in the value, where a negative percentage change indicates a decrease in the value. The results are reported as estimated means ± standard deviation (SD). Data were analysed for statistical significance, using an independent t-test. The t-test was performed to compare the skin characteristics between Caucasian and African test subjects, when comparing the dominant and control hand and different areas.

A p value of ≤ 0.05 was regarded as significant.

Results

Tables 4 - 6 contain the baseline values and experimental values obtained from Caucasian and African test subjects for hydration, TEWL and skin surface pH.

A,B,C indicates the baseline values obtained on the same day the corresponding barrier cream was tested (A: Gloves In A Bottle™, B: Reinol™, C: Travabon™)

Table 4: (a)The stratum corneum hydration baseline values

CAUCASIAN						
AREAS	**A** **(Est Mean ±SD)**	Interpretation	**B** **(Est Mean ±SD)**	Interpretation	**C** **(Est Mean ±SD)**	Interpretation
Forearm	24.3 ± 4.9	Very dry	36.9 ± 4.1	Dry	22.9 ± 6.5	Very dry
Back of hand	21.7 ± 4.0	Very dry	36.4 ± 8.1	Dry	24.2 ± 6.7	Very dry
Palm	18.2 ± 6.4	Very dry	21.4 ± 5.1	Very dry	19.8 ± 7.8	Very dry
Wrist	20.3 ± 6.4	Very dry	18.6 ± 1.1	Very dry	19.3 ± 4.1	Very dry
AFRICAN						
AREAS	**A** **(Est Mean ±SD)**	Interpretation	**B** **(Est Mean ±SD)**	Interpretation	**C** **(Est Mean ±SD)**	Interpretation
Forearm	29.6 ± 1.5	Very dry	29.0 ± 2.6	Very dry	31.2 ± 2.0	Very dry
Back of hand	29.1 ± 31.	Very dry	26.8 ± 3.1	Very dry	27.3 ± 2.8	Very dry
Palm	15.0 ± 5.1	Very dry	17.6 ± 4.3	Very dry	19.2 ± 5.8	Very dry
Wrist	34.9 ± 3.3	Moisturised	26.2 ± 4.1	Very dry	24.1 ± 4.3	Very dry

(b) Stratum corneum hydration values after the application of the barrier creams from 2-8 hours.

CAUCASIAN						
AREAS	**Gloves in a bottle™** **(Est Mean ±SD)**	Interpretation	**Reinol™** **(Est Mean ±SD)**	Interpretation	**Travabon™** **(Est Mean ±SD)**	Interpretation
Forearm	30.4 ± 1.6	Very dry	48 ± 0.4	Moisturised	17 ± 3.9	Very dry
Back of hand	27.7 ± 1.0	Very dry	48 ± 0.4	Moisturised	18.6 ± 2.7	Very dry
Palm	19.9 ± 1.4	Very dry	31 ± 0.9	Dry	17 ± 0.4	Very dry
Wrist	24.4 ± 0.9	Very dry	24 ± 0.6	Very dry	11.9 ± 1.9	Very dry
AFRICAN						
AREAS	**Gloves in a bottle™** **(Est Mean ±SD)**	Interpretation	**Reinol™** **(Est Mean ±SD)**	Interpretation	**Travabon™** **(Est Mean ±SD)**	Interpretation
Forearm	32.5 ± 0.1	Dry	31.7 ± 0.1	Dry	18.3 ± 1.6	Very dry
Back of hand	31.5 ± 0.5	Dry	31.7 ± 0.4	Dry	21.3 ± 1.0	Very dry
Palm	17.4 ± 0.4	Very dry	21.2 ± 0.3	Very dry	13.4 ± 0.3	Very dry
Wrist	48.4 ± 0.5	Moisturised	29.8 ± 0.8	Very dry	18.3 ± 1.5	Very dry

The majority of hydration values were low before the barrier creams was applied. After the barrier creams were applied, Gloves In A Bottle™ and Travabon™ affected the skin hydration values although not enough that the interpretation of the values changed. Reinol™ had the most moisturising effect on the skin for Caucasians, and for African test subjects resulted in very dry to dry skin interpretation values.

Table 5: (a) TEWL baseline values

CAUCASIAN						
AREAS	**A** (Est Mean ±SD)	Interpretation	**B** ((Est Mean ±SD)	Interpretation	**C** (Est Mean ±SD)	Interpretation
Forearm	16.6 ± 3.9	Normal	17.9 ± 4.3	Normal	16.3 ± 4.5	Normal
Back of hand	11.3 ± 3.0	Healthy	12.0 ± 2.7	Healthy	10.9 ± 2.6	Healthy
Palm	33.4 ± 3.6	Critical	32.0 ± 3.5	Critical	31.7 ± 4.2	Critical
Wrist	12.2 ± 3.4	Healthy	24.0 ± 4.0	Strained	10.4 ± 4.4	Healthy
AFRICAN						
AREAS	**A** (Est Mean ±SD)	Interpretation	**B** (Est Mean ±SD)	Interpretation	**C** (Est Mean ±SD)	Interpretation
Forearm	14.2 ± 3.0	Normal	12.7 ± 2.0	Healthy	15.4 ± 1.6	Normal
Back of hand	11.4 ± 3.4	Healthy	11.2 ± 2.1	Healthy	11.8 ± 2.9	Healthy
Palm	31.0 ± 2.6	Critical	31.3 ± 1.5	Critical	32.0 ± 1.5	Critical
Wrist	11.9 ± 3.9	Healthy	12.5 ± 2.4	Healthy	13.0 ± 3.1	Healthy

(b) TEWL values after the application of the barrier creams from 2-8 hours

CAUCASIAN						
AREAS	**Gloves in a bottle™** (Est Mean ±SD)	Interpretation	**Reinol™** (Est Mean ±SD)	Interpretation	**Travabon™** (Est Mean ±SD)	Interpretation
Forearm	11.5 ± 0.1	Healthy	11.5 ± 0.4	Healthy	9.4 ± 0.3	Very healthy
Back of hand	16.6 ± 0.3	Normal	17.2 ± 2.3	Healthy	10.2 ± 0.6	Healthy
Palm	33.6 ± 0.4	Critical	36.3 ± 8.1	Critical	28.8 ± 0.8	Critical
Wrist	12.4 ± 0.1	Healthy	12.4 ± 0.5	Healthy	10.0 ± 0.2	Healthy
AFRICAN						
AREAS	**Gloves in a bottle™** (Est Mean ±SD)	Interpretation	**Reinol™** (Est Mean ±SD)	Interpretation	**Travabon™** (Est Mean ±SD)	Interpretation
Forearm	11.5 ± 0.6	Healthy	9.7 ± 0.7	Healthy	8.4 ± 0.9	Very healthy
Back of hand	11.1 ± 0.6	Healthy	11.1 ± 0.8	Healthy	10.9 ± 1.3	Healthy
Palm	31.7 ± 0.9	Critical	28.5 ± 0.3	Critical	28.8 ± 1.7	Critical
Wrist	11.3 ± 0.3	Healthy	10.2 ± 0.5	Healthy	8.8 ± 1.1	Very healthy

The baseline values had a variation between a critical interpretation of the palm and a healthy interpretation of the back of hand and wrist. Gloves In A Bottle™ had no significant effects for Caucasian and African test subjects. Reinol™ decreased TEWL on the African test subjects but had no significant effect on the Caucasian test subjects. Travabon™ decreased TEW for both Caucasian and African test subjects.

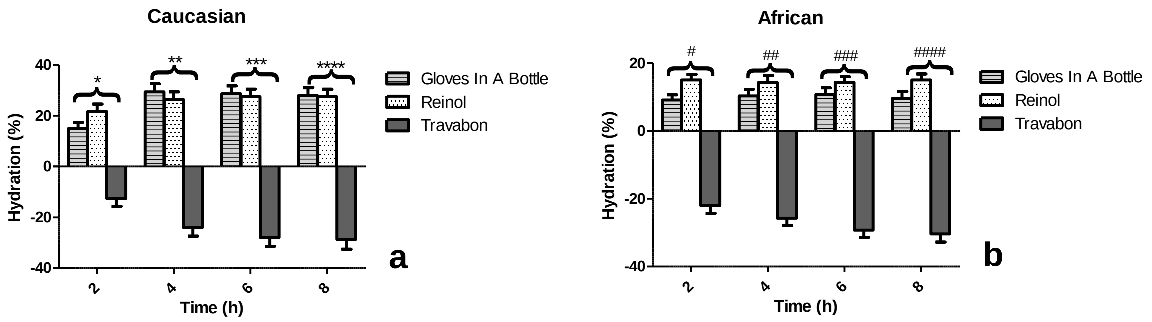
Table 6: (a) Skin surface pH baseline values

CAUCASIAN						
AREAS	**A** (Est Mean ±SD)	Interpretation	**B** (Est Mean ±SD)	Interpretation	**C** (Est Mean ±SD)	Interpretation
Forearm	5.8 ± 0.5	High skin pH	5.6 ± 0.6	Normal	5.8 ± 0.4	High skin pH
Back of hand	6.0 ± 0.4	High skin pH	5.9 ± 0.5	High skin pH	6.0 ± 0.7	High skin pH
Palm	5.7 ± 0.5	High skin pH	5.4 ± 0.5	Normal	5.8 ± 0.3	High skin pH
Wrist	5.9 ± 0.7	High skin pH	5.7 ± 0.7	High skin pH	5.9 ± 0.6	High skin pH
AFRICAN						
AREAS	**A** (Est Mean ±SD)	Interpretation	**B** (Est Mean ±SD))	Interpretation	**C** (Est Mean ±SD)	Interpretation
Forearm	5.7 ± 0.3	High skin pH	5.6 ± 0.4	High skin pH	6.5 ± 0.2	High skin pH
Back of hand	5.8 ± 0.3	High skin pH	5.8 ± 0.4	High skin pH	6.4 ± 0.4	High skin pH
Palm	5.7 ± 0.2	High skin pH	5.4 ± 0.5	Normal	6.5 ± 0.4	High skin pH
Wrist	5.8 ± 0.4	High skin pH	5.3 ± 0.5	Normal	6.4 ± 0.2	High skin pH

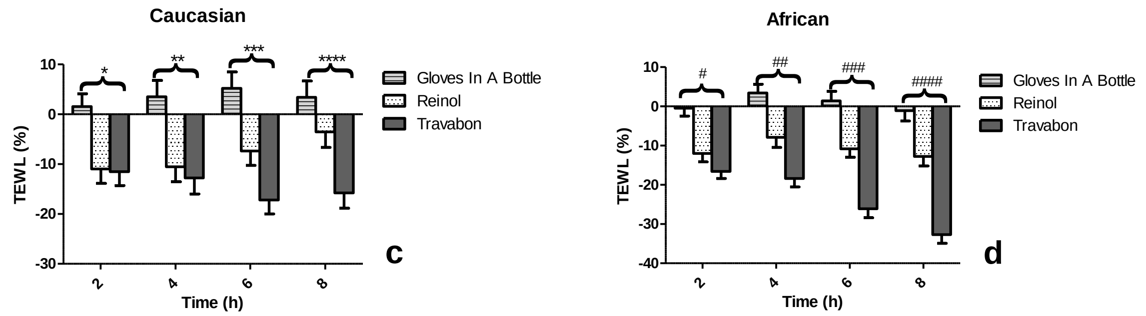
(b) pH values after the application of the barrier creams from 2-8 hours

CAUCASIAN						
AREAS	**Gloves in a bottle™** (Est Mean ±SD)	Interpretation	**Reinol™** (Est Mean ±SD)	Interpretation	**Travabon™** (Est Mean ±SD)	Interpretation
Forearm	6.4 ± 0.09	High skin pH	5.8 ± 0.09	High skin pH	5.7 ± 0.01	High skin pH
Back of hand	6.2 ± 0.11	High skin pH	5.4 ± 0.08	Normal	5.7 ± 0.04	High skin pH
Palm	5.8 ± 0.14	High skin pH	5.3 ± 0.02	Normal	5.4 ± 0.08	Normal
Wrist	6.5 ± 0.13	High skin pH	5.6 ± 0.16	Normal	5.7 ± 0.03	High skin pH
AFRICAN						
AREAS	**Gloves in a bottle™** (Est Mean ±SD)	Interpretation	**Reinol™** (Est Mean ±SD)	Interpretation	**Travabon™** (Est Mean ±SD)	Interpretation
Forearm	6.8 ± 0.8	High skin pH	6.1 ± 0.08	High skin pH	5.7 ± 0.1	High skin pH
Back of hand	6.6 ± 0.8	High skin pH	5.3 ± 0.09	Normal	5.8 ± 0.06	High skin pH
Palm	7.1 ± 1.3	High skin pH	5.5 ± 0.03	Normal	5.7 ± 0.03	High skin pH
Wrist	6.7 ± 0.13	High skin pH	6.0 ± 0.05	High skin pH	5.9 ± 0.05	High skin pH

The majority of baseline measurements were high for both Caucasian and African test subjects. Gloves In A Bottle™ increased pH for both Caucasian and African test subjects, but because the baseline values were high from the beginning the values were not significant enough to change the interpretation. Reinol™ decreased pH of the back of hand and wrist and increased pH in the forearm of Caucasian test subjects and for African test subjects the pH decreased at the back of hand and increased pH on the forearm, palm and wrist. Travabon™ decreased pH values for both Caucasian and African test subjects although this change was not enough to change the interpretation of pH.



#; *; indicates statistical significance



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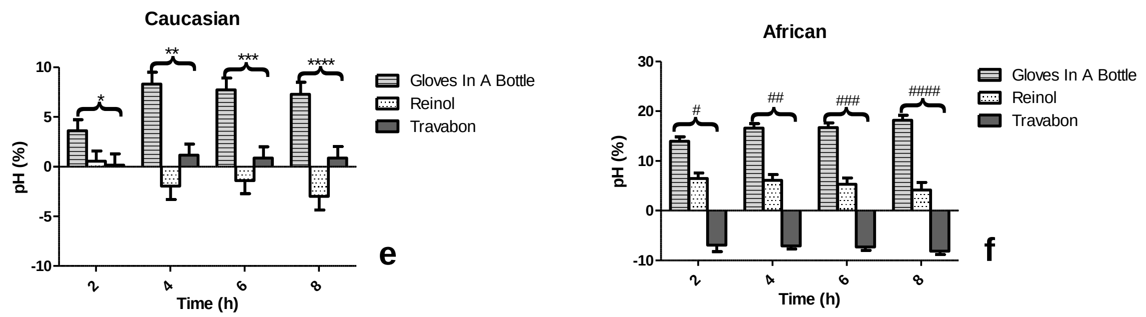


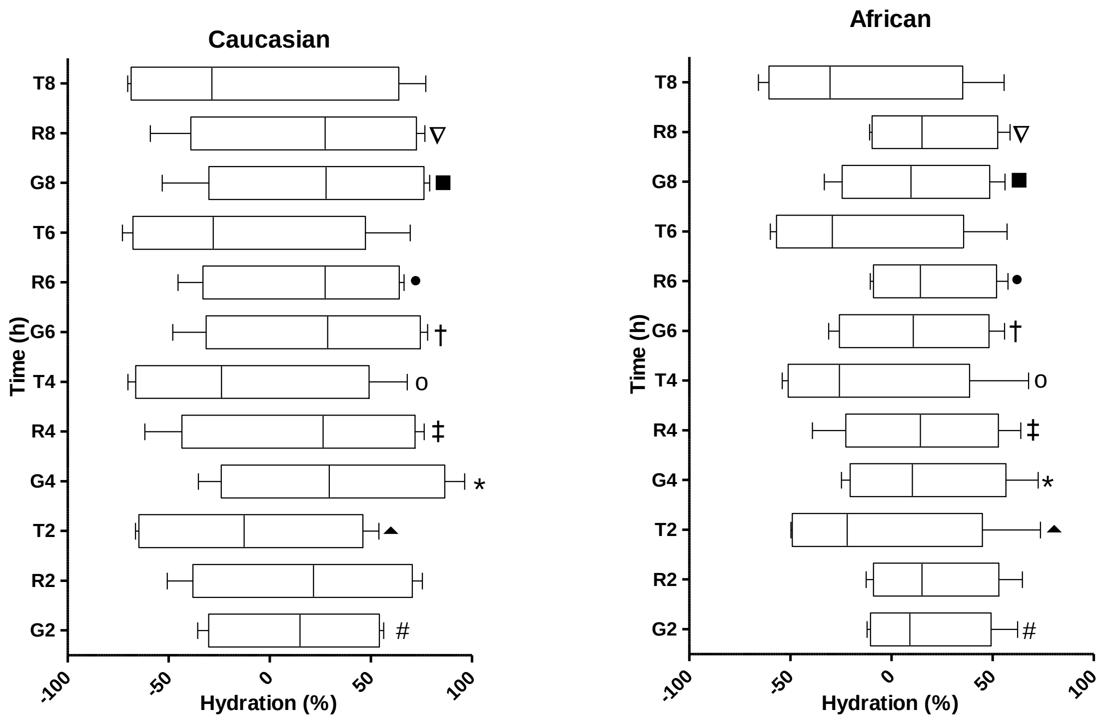
#; *; indicates statistical significance

Figure 2: (a - f) Comparison of the effect of the three different barrier creams on stratum corneum hydration, TEWL and pH of Caucasian and Africa skin at different time intervals.

For Figure 2 (a - f) All three barrier creams had significant differences on stratum corneum hydration over an 8 hour period. TEWL and skin surface pH also had significant difference for both Caucasian test subjects and African test subjects.

Note: Figures 3 - 5 are only applicable on the values obtained from the experimental hands and arms where the three barrier creams were applied (min, mean, maximum ± SD).

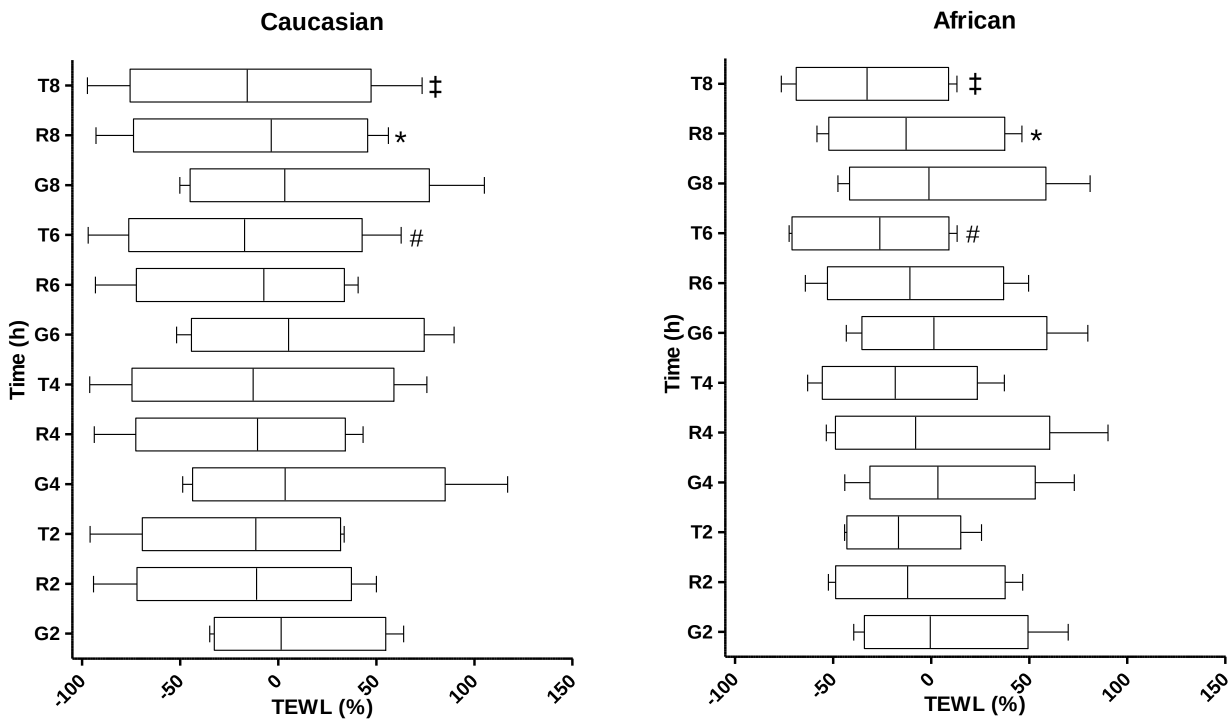
Figure 3 illustrates the stratum corneum hydration of the skin for the three different barrier creams G (Gloves In A Bottle™), R (Reinol™) and T (Travabon™) over an 8 hour time period. Gloves In A Bottle™ showed significant differences in hydration over 2, 4, 6, 8 hours between Caucasian and African test subjects. Reinol™ showed significant differences in the effects of hydration at 4, 6, 8 hours, between the races where Travabon™ only showed differences at 2 and 4 hours between Caucasian and African test subjects.



#;▲; *; ‡; o; †; •; ■; ▽ indicates statistical significance ($p < 0.05$).

Figure 3: Variation of the stratum corneum hydration (in percentage difference) between three different barrier creams for Caucasian and African test subjects over an 8 hour period.

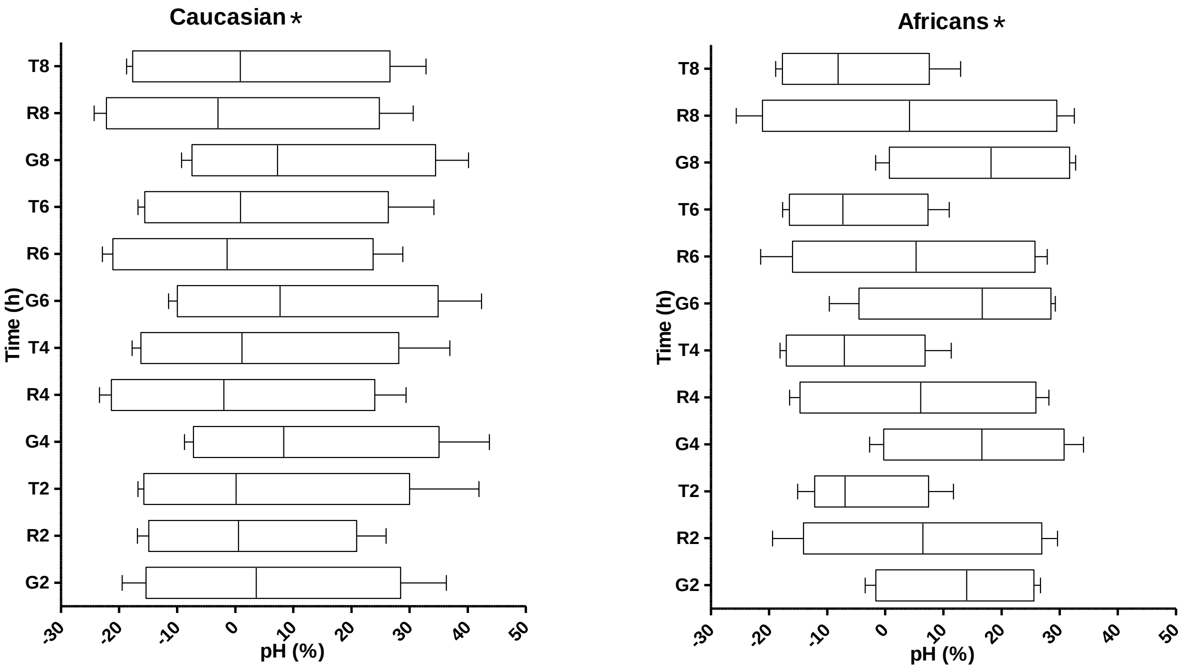
Figure 4 illustrates the TEWL of the skin for the three different barrier creams G (Gloves In A Bottle™), R (Reinol™) and T (Travabon™) over an 8 hour time period. There were significant differences in the effects of Travabon™ at 6 and 8 hours between Caucasian and African test subjects. There was also significant differences in the effects of Reinol™ on TEWL at 8 hours between Caucasian and African test subjects.



#; *; ‡; indicates statistical significance

Figure 4: Variation of the TEWL (in percentage difference) between three different barrier creams for Caucasian and African test subjects over an 8 hour period.

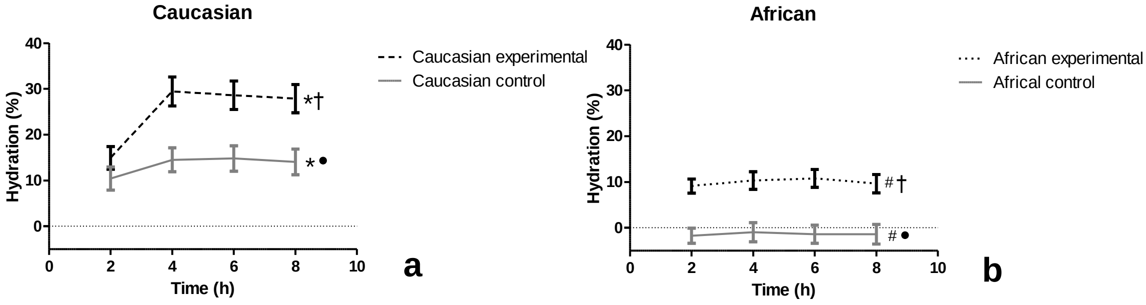
Figure 5 illustrates the pH of the skin surface for the three different barrier creams G (Gloves In A Bottle™), R (Reinol™) and T (Travabon™) over an 8 hour time period. The pH values for Caucasian and African test subjects were all significantly different from each other (p<0.005) at each time interval. For clarity of Figure 5 the significance is not shown at every time interval.



* indicates statistical differences

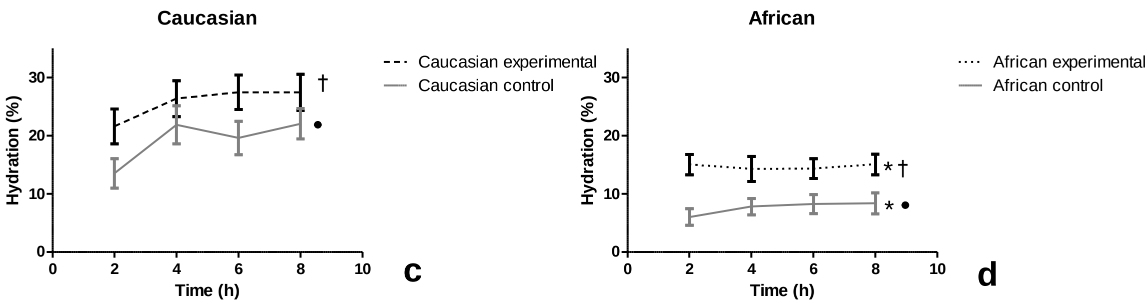
Figure 5: Variation of the pH (in percentage) between three different barrier creams for Caucasian and African test subjects over an 8 hour period.

Gloves In A Bottle™



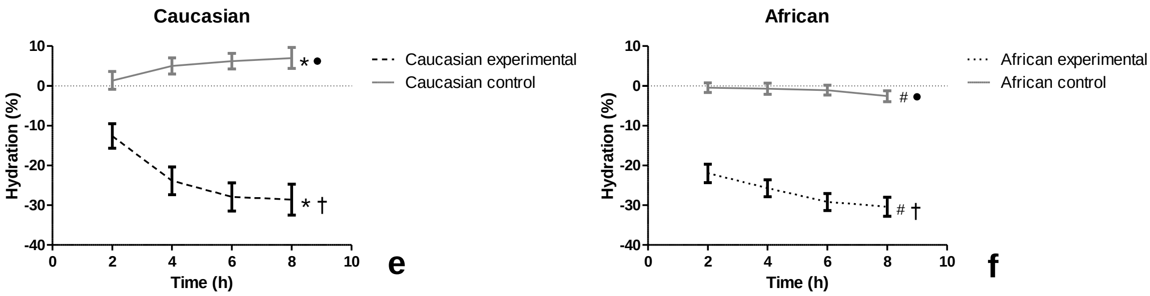
†;•;*;# indicates statistical significance.

Reinol™



†;•;*;# indicates statistical significance.

Travabon™



†;•;*;# indicates statistical significance.

Figure 6 (a - f): Comparison of stratum corneum hydration between the experimental and control hand of Caucasian and African test subjects.

In Figure 6 (a) the skin hydration of Caucasian test subjects showed significant differences between experimental and control hand with the application of Gloves In A Bottle™ and (e) Travabon™ but not for (c) Reinol™. African test subjects showed significantly different (b) (d) (f) hydration for all three barrier creams between experimental and control hands. The hydration differed significantly between Caucasian and African test subjects on both experimental and control hands for all three types of barrier creams.

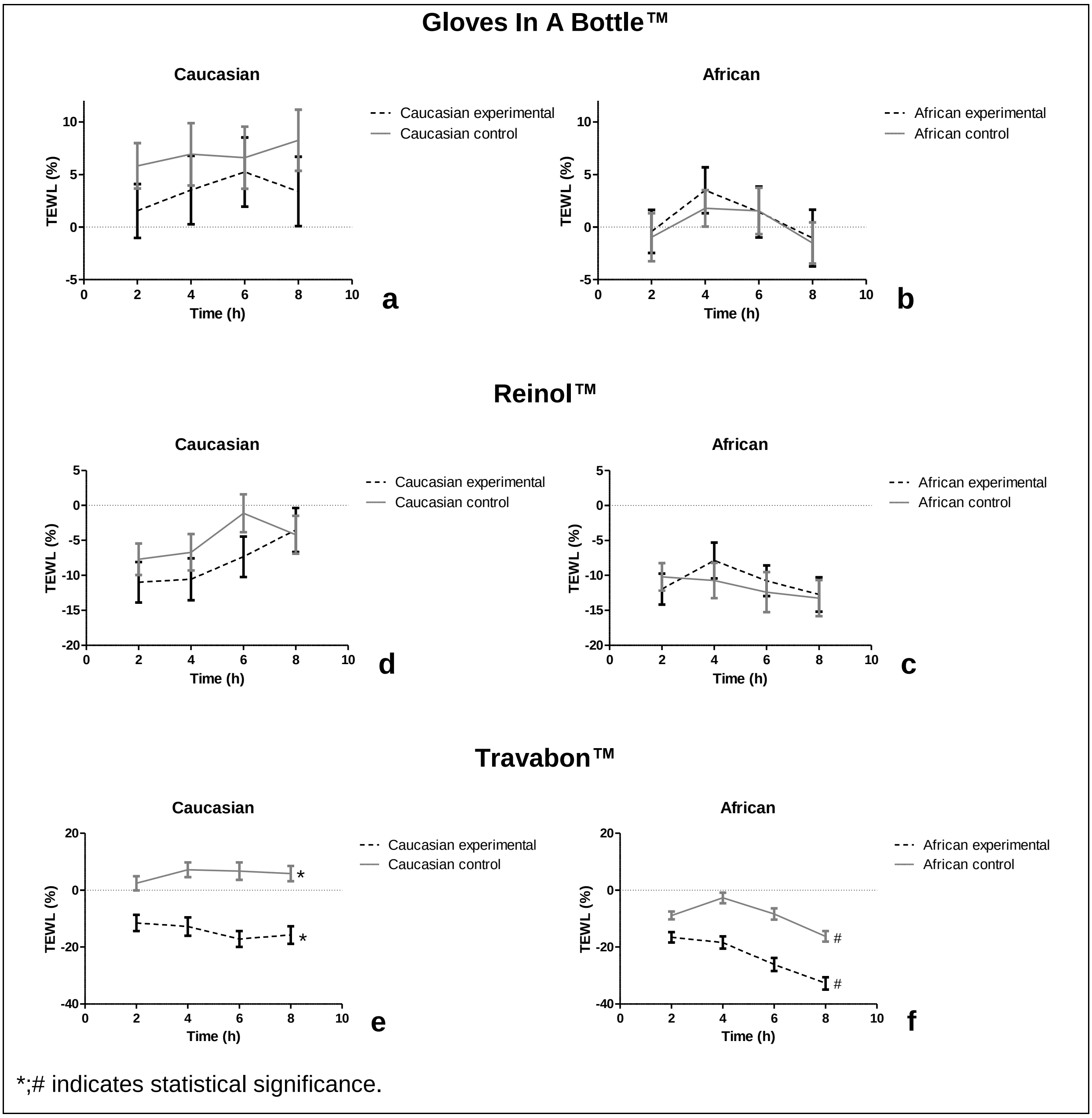
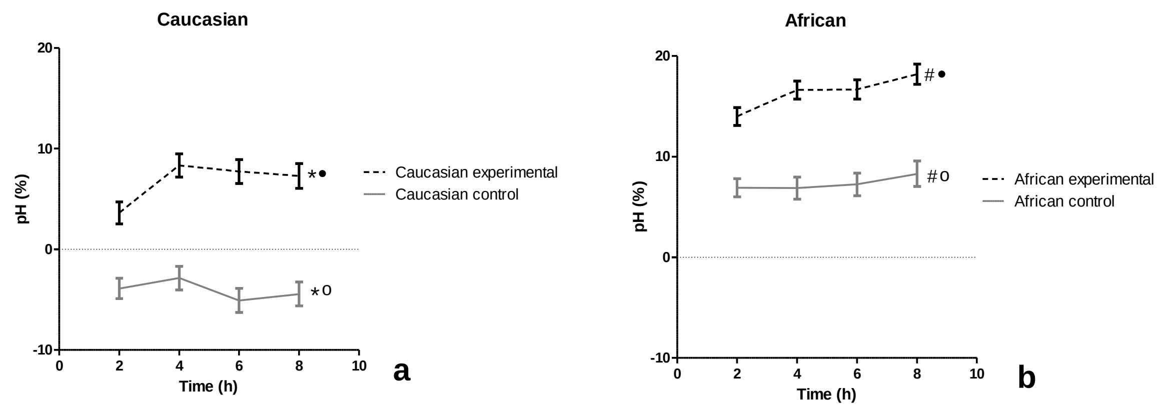


Figure 7 (a – f): Comparison of TEWL between the experimental and control hand of Caucasian and African test subjects.

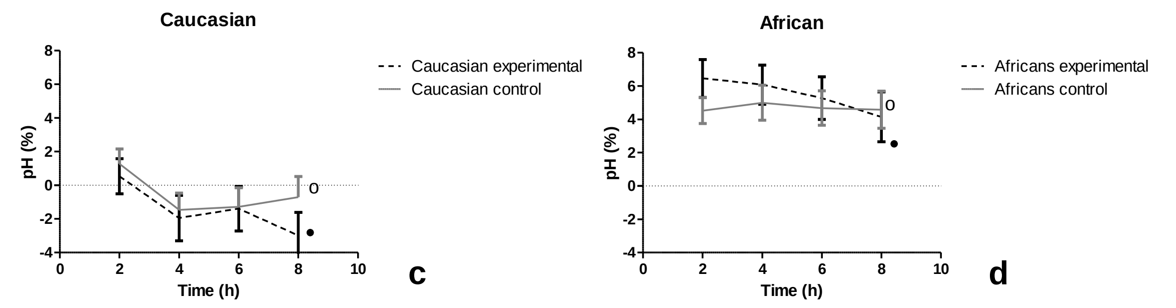
In Figure 7 (a - c) there was no significant difference in TEWL with the application of Gloves In A Bottle™ or Reinol™ between the Caucasian and African test subjects' experimental and control hands. With the application of Travabon™ there were, however, significant differences in TEWL between the experimental and control hands of Caucasian and African test subjects.

Gloves In A Bottle™



o;•;*;# indicates statistical significance.

Reinol™



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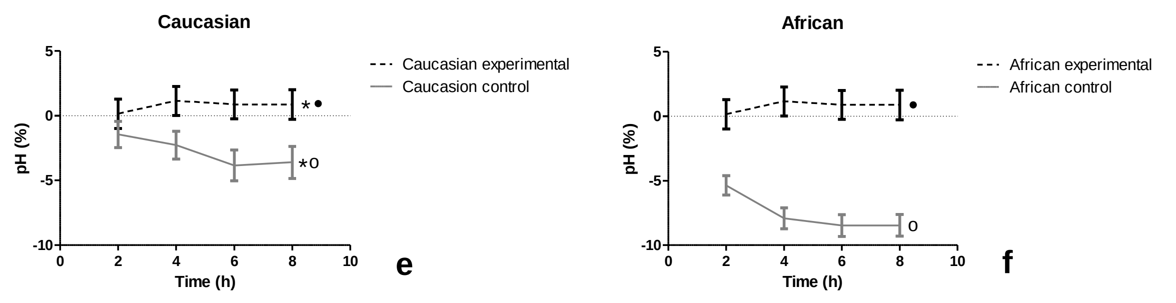
Travabon™

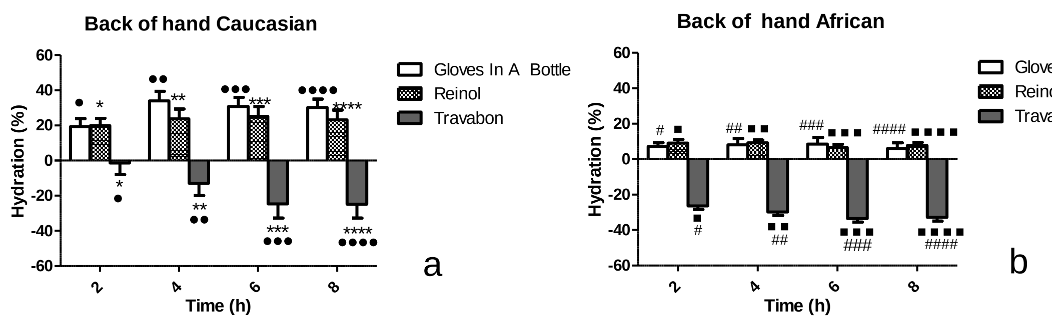


o; •;* indicates statistical significance.

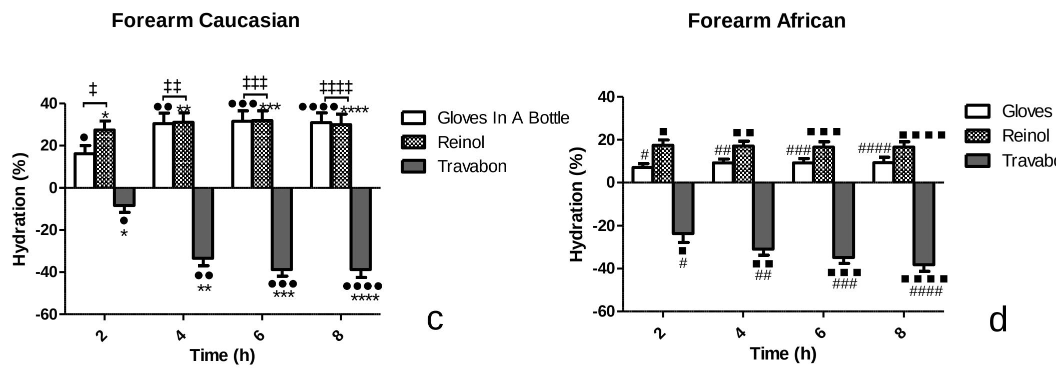
Figure 8 (a – f): Comparison of skin pH between the experimental and control hand of Caucasian and African test subjects.

In Figure 8 (a) and (e) the pH with the application of Gloves In A Bottle™ and Travabon™ differed significantly between experimental and control hands of Caucasian test subjects. The African test subjects only showed significant difference in the pH with the application of Gloves In A Bottle™ between experimental and control hands. As also seen in Figure 5 there were significant difference in all the pH measurements between Caucasian and African test subjects.

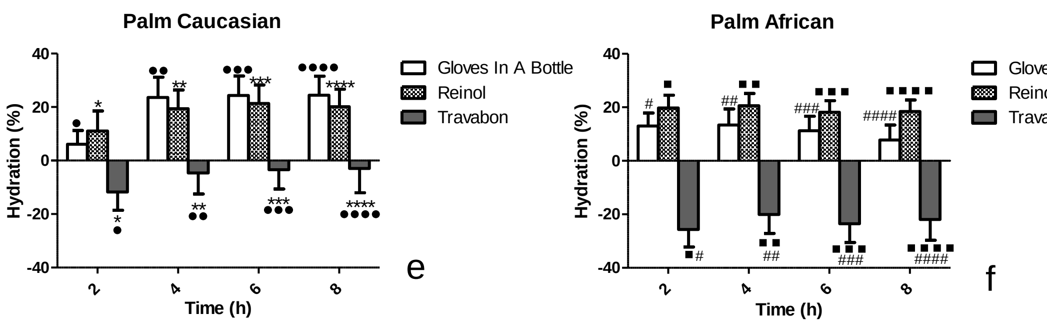
Areas sampled
Hydration



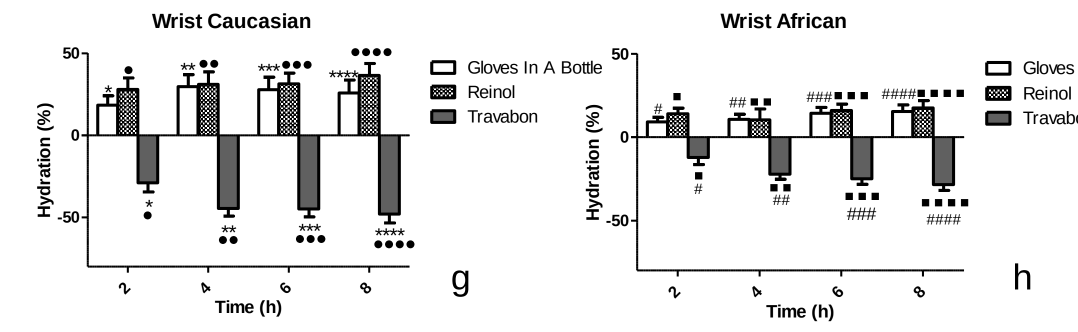
■;●;*;# indicates statistical significance.



†;●; ■;*;# indicates statistical significance.



■; ●;*;# indicates statistical significance.

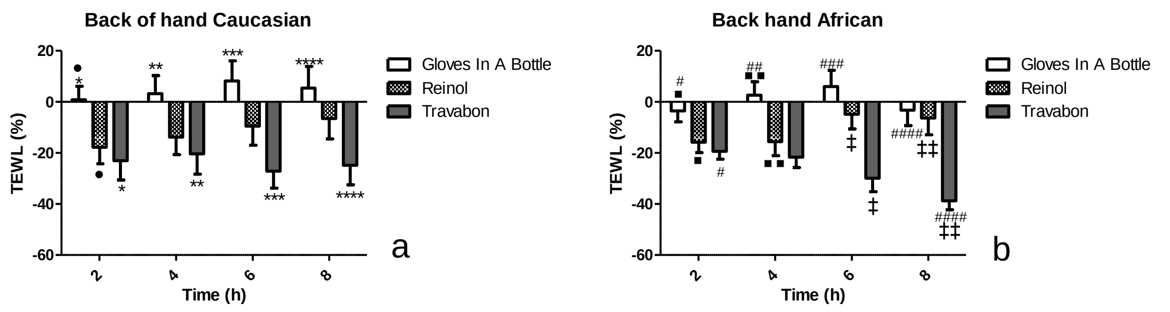


■;●;*;# indicates statistical significance.

Figure 9: Comparison of the effects of the three different barrier creams on stratum corneum hydration with regards to the different measuring areas (a – h).

For the back of hand, forearm, palm and wrist the effects of Gloves In A Bottle™ was significantly different from the effects of Travabon™. The effects of Reinol™ on hydration was also significantly different from the effects of Travabon™ for 2 - 8 hours in both Caucasian and African test subjects

TEWL



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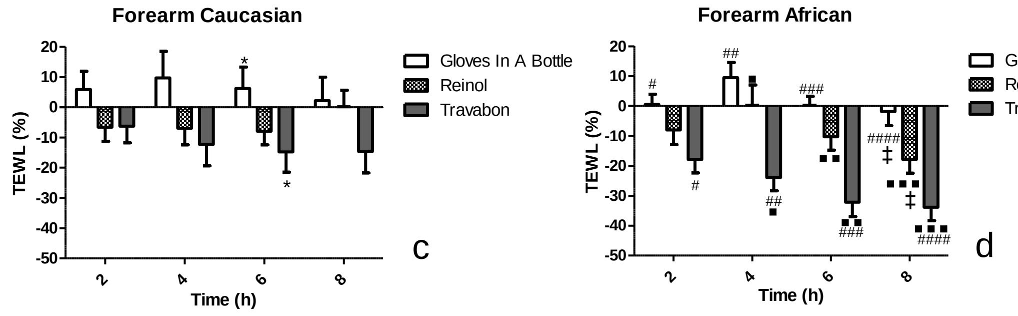
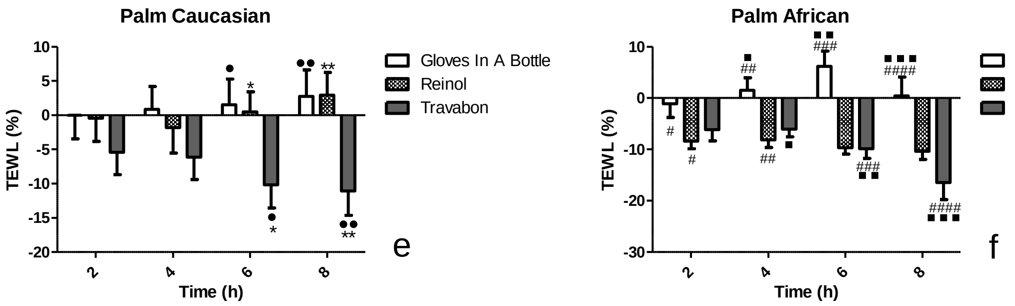
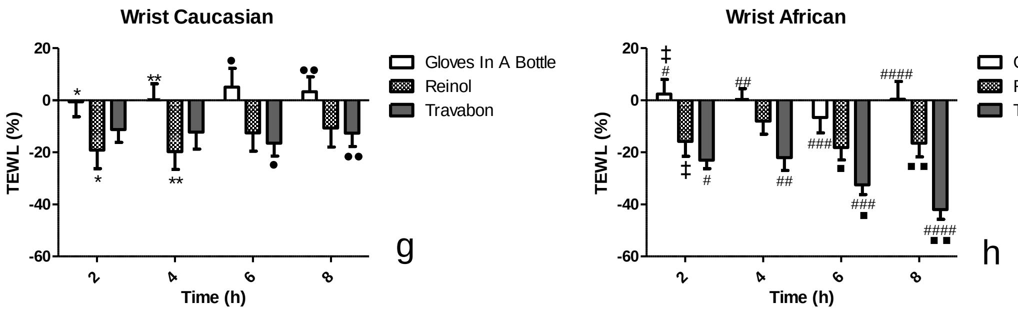


■; *;# indicates statistical significance.



•;■;*;# indicates statistical significance.

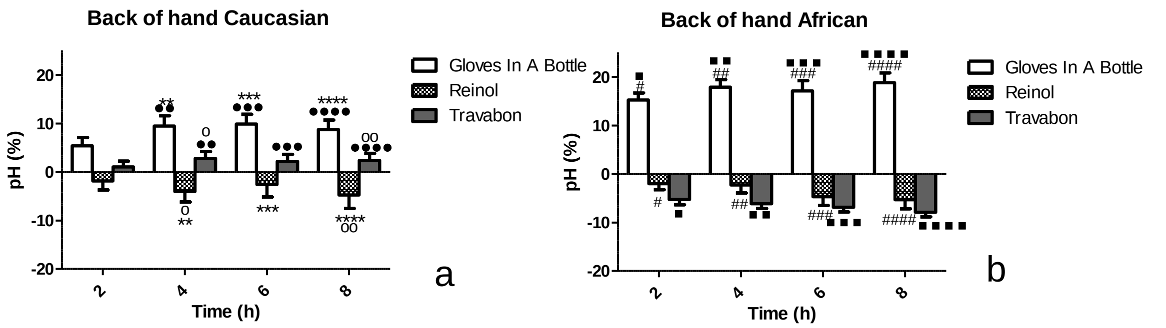


†;•;■;*;# indicates statistical significance.

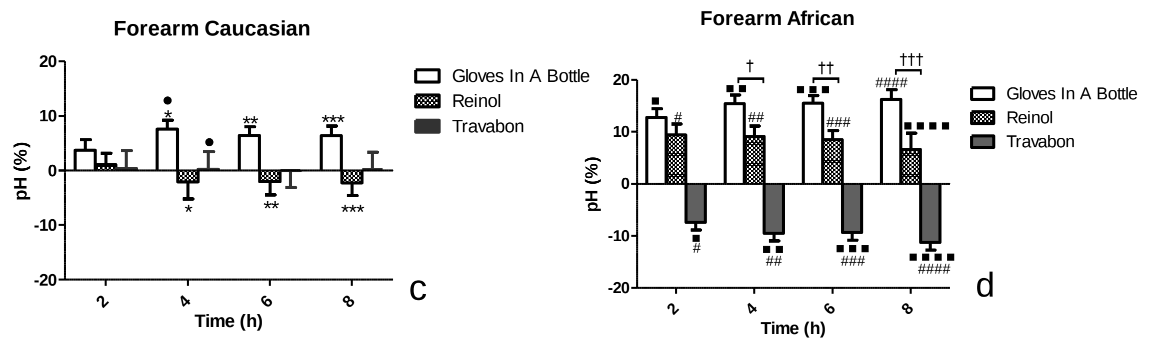
Figure 10: Comparison of the effects of the three different barrier creams on TEWL with regards to the different measuring areas (a – h).

TEWL decreased on the back of hand, forearm, palm and wrist with the application of Reinol™ and Travabon™, whereas Gloves In A bottle™ led to almost constant TEWL. Gloves In A Bottle™ showed small changes in TEWL increasing and decreasing values in various areas. Reinol™ and Travabon™ had decreased effects TEWL for both Caucasian and African test subjects.

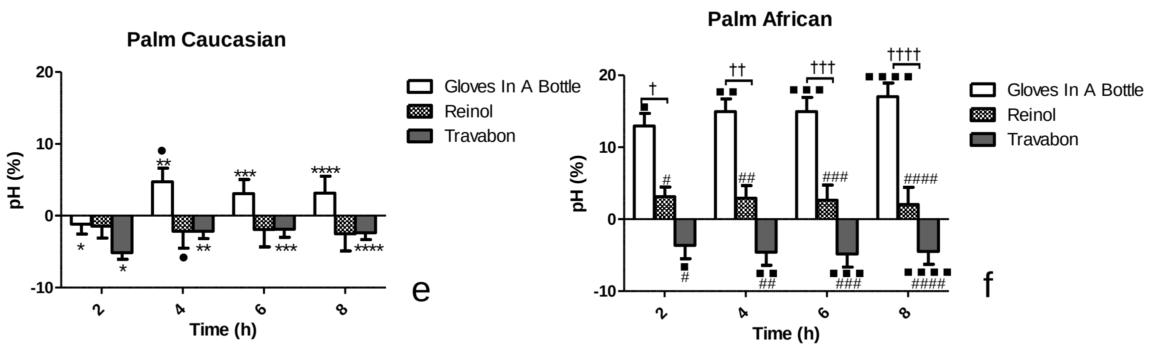
Skin surface pH



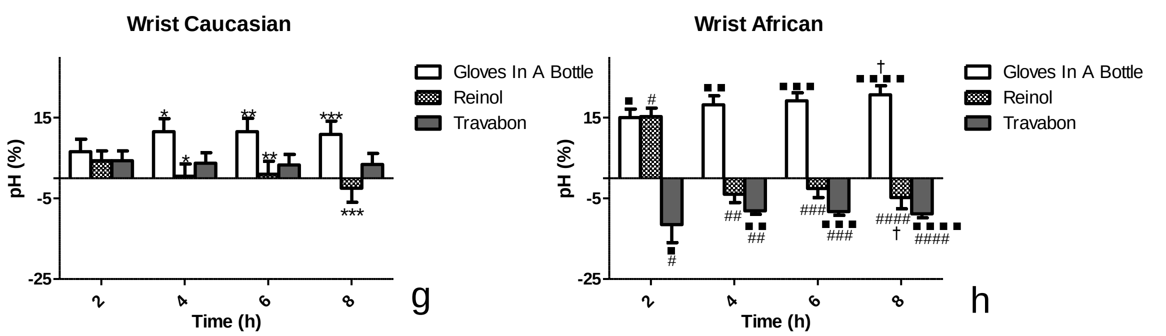
o;•;■;*;# indicates statistical significance.



•;■;* indicates statistical significance.



†;•;■;*;# indicates statistical significance.



†;•;■;*;# indicates statistical significance.

Figure 11: Comparison of the effects of the three different barrier creams on skin surface pH with regards to the different measuring areas (a – h).

Gloves In A Bottle™ increased pH at all four anatomical areas in both Caucasian and African test subjects. Reinol™ decreased pH at the back of hand, forearm and palm, and a slight increase at the wrist of the Caucasian test subjects. Reinol™ increased pH at the forearm and palm and decreased pH at the back of hand and wrist of the African test subjects. Travabon™ decreased pH at African test subjects for all four anatomical areas, with increasing and decreasing pH at Caucasian test subjects.

Discussion

Hydration

The baseline values measured for stratum corneum hydration varied between very dry and moisturised, however the majority of values were very dry. This indicated that the test subjects' skin was already dry before the studies commenced. After Travabon™ was applied to the test subjects' skin it formed a hard whitish layer on the skin, that didn't rub off easily in the workplace and couldn't be removed when conventional hand washing took place. One of the ingredients in Travabon™ is talc, when in powder form it acts as an astringent that can contribute to the dry-feeling, Travabon™ decreased hydration values although not enough to change the interpretation. Reinol™ had the most moisturising effect on the skin for the Caucasian test subjects in their forearm and back of hand, while the values went from very dry to a dry skin of the African test subjects. Reinol™ had a very greasy appearance and easily rubbed off on the clothes of the test subjects. The greasiness could contribute to higher moisture of the skin. Gloves In A Bottle™ dried quickly after it was applied on the skin surface, the values reflected a dry skin except for the wrist of African test subjects being moisturised but the wrist was also moisturised before the application. The skins appearance will be soft and flexible when there is an adequate amount of water in the stratum corneum and this represents an intact skin barrier (Alanen *et al.,* 2004). Therefore, it is important to choose the correct barrier cream for a specific exposure and under the correct workplace conditions.

Gloves In A Bottle™ is a silicone repellent barrier cream for organic agents, Reinol™ is a water-repellent barrier cream used for wet work and Travabon™ is an oil repellent barrier cream that is used for oils, grease and other oily substances in the industry. The critical function of water in the stratum corneum is to participate in hydrolytic enzymatic processes required for normal desquamation. If stratum corneum water content falls below a critical level, enzymatic function required for normal desquamation is impaired, leading to corneocyte adhesion and accumulation of corneocytes on the cutaneous surface. These changes correspond with the visible appearance of dryness, roughness, scaling, and flaking of the skin surface.

When the skin is dry the skin barrier could become impaired and the stratum corneum fails to retain water (Darlenski *et al.,* 2009).

In Figure 2 all three different barrier creams in terms of stratum corneum hydration showed significant differences from each other for the Caucasian and African test subjects. Reinol™ again proved to increase the hydration state the most and Travabon™ decreased the hydration state. A study by Barel and Clarys (2006) stated that the efficacy of topically applied agents depends on their effect in increasing the skin surface hydration state. These results clearly shows Travabon™ as the barrier cream that decreased stratum corneum hydration the most for both Caucasian and African test subjects.

A decrease in hydration will cause dryness of the skin which leads to impaired barrier function (Darlenski *et al.,* 2009). When examining Figure 3, the hydration percentage for Gloves In A Bottle™ increased from 52% at 2 hours to 80% at 4 hours there after 60%. Gloves In A Bottle™ and Travabon's™ overall variation of the percentage change are different from each other where Travabon's™ variation had a more negative percentage change, indicating that hydration decreased with Travabon™. Reinol™ and Travabon™ were significantly different from 2 - 8 hours ($p < 0.0000$). Gloves In A Bottle™ increased the hydration the most after 4 hours although these increases in hydration were not enough to change the very dry interpretation of the skin as seen in Table 4. Reinol™ increased hydration as seen in Table 4 where after 4 hours the hydration stayed consistent. For the African test subjects the three barrier creams showed a more positive variation, the effects of Reinol™ was consistent with the effects of Gloves In A Bottle™ whereas the effects of Travabon™ showed a negative variation. Thus variation also shows the decreasing effect of Travabon™ on stratum corneum hydration as seen in Table 4 of both Caucasian and African test subjects.

Figure 6 indicated the difference in effect of the barrier creams in Caucasian and African experimental and control hands. The comparison between Caucasian experimental and control (Figure 6a) for Gloves In A Bottle™ showed significant differences ($p < 0.0010$). The hydration of the Caucasian experimental hand increased after 2 hours, whereas the control hand stayed consistent. For the African test subjects the hydration state increased slightly above the control hand with Gloves In A Bottle™ and there was a significant difference ($p < 0.00014$) between the experimental and control hand. Reinol™ led to an 8% increase in the hydration state of the Caucasian experimental hand compared to the Caucasian control hand although this increase was not significant. The application of Reinol™ on African test subjects showed a constant level of hydration and significant difference ($p < 0.0017$) between the experimental and control hand. Travabon™ decreased the skin's hydration as can be seen by the negative values shown on the graphs. The experimental hand showed significant differences between the experimental and control hand ($p < 0.0001$) of both Caucasian and African test subjects. The difference can clearly be seen in Figure 6 as both Gloves In A Bottle™ and Reinol™ increased hydration above the control values, whereas Travabon™ decreased the hydration significantly in both Caucasian and African test subjects.

Comparing Caucasian experimental to African experimental there were significant differences between both hands respectively. It is evident in this study that after a barrier cream was applied that ethnic differences in stratum corneum hydration were significant for all three barrier creams. These results proved that there are ethnical differences in the baseline hydration state of Caucasian and African test subjects and that the skin of different races react differently to the barrier creams. Travabon™ shows a drastic decrease in hydration state, whereas Gloves In A Bottle™ from Figure 6a showed an increased in hydration on the experimental hand. The increase in hydration caused by Gloves In A Bottle™ was, however, not enough to change the interpretation of the skin values from Table 4, therefore the values remained very dry, whereas Reinol™ had a hydrating effect on some areas which changed the interpretation of the skin values.

When comparing the anatomical areas Travabon™ led to a decrease in hydration in all the areas whereas Gloves In A Bottle™ and Reinol™ increased hydration. Gloves In A Bottle™ and Reinol™ only differed significantly at the forearm of the Caucasian test subjects. Travabon™ decreased hydration in all four anatomical areas for Caucasian and African test subjects. Both Barel and Clarys (2006) and

Farinelli and Berardesca (2006) have stated that stratum corneum hydration differs between anatomical areas, where these values are high on the forearm, palm and hand. These results showed that the forearm for Caucasian subjects had the highest hydration values and lower hydration values for the African test subjects; the palm hydration was also high with the lowest hydration values in die back of hand for Caucasian and African test subjects.

TEWL

From the baseline values in Table 5 it can be seen that Gloves In A Bottle™ had no significant effect on Caucasian or African test subjects. Reinol™ showed no significant effect on Caucasian test subjects, but decreased TEWL for African test subjects although not enough to change the interpretation. Similarly Travabon™ decreased TEWL values for both Caucasian and African test subjects however this decrease did not change the interpretation. TEWL varies in different anatomical areas and will attribute to the regional variation in the total lipid content of the stratum corneum (Farinelli and Berardesca, 2006). The three types of barrier cream showed varying effects on TEWL measurements for the anatomical areas. Travabon™ led to very healthy skin TEWL in the different anatomical areas whereas Gloves In A Bottle™ did not have a significant effect on TEWL. The palm area was critical in both Caucasian and African test subjects even before the start of the study and stayed critical after the barrier creams were applied. Reinol™ and Travabon™ improved TEWL which can be seen from Table 5, since the application of these barrier creams decreased TEWL and led to very healthy interpretations.

From Figure 2 it is clear that TEWL in Caucasian and African test subjects TEWL for all three barrier creams were significantly different from each other. In both Caucasian and African tests subjects Reinol™ and Travabon decreased TEWL of the skin. When there is an increase in TEWL it is a reflection of a diseased and damaged skin and also an impaired skin barrier (Levin and Maibach, 2005). Therefore, a decrease in TEWL shows that the skin barrier was intact when using Travabon™. African test subjects had lower TEWL compared to Caucasian test subjects, this could be because African skin is more resistant to mechanical challenge to the stratum corneum and therefore have lower TEWL (Rawlings, 2010).

From Figure 4 it is clear that for the Caucasian test subjects Gloves In A Bottle's™ led to an increase in TEWL, and showed a more positive variation especially after 4 hours when TEWL increases. The mean percentage change in TEWL with the application of Reinol™ increased over 8 hours, although the variation of data was more negative. Travabon™ caused a constant decrease in TEWL. For Travabon™ there was significant differences between Caucasian and African test subjects after 6 and 8 hours. With the African test subjects Gloves in A Bottle™ led to a slight increase in TEWL, Travabon™ increased to a more negative spread and Reinol™ increased after 4 hours. Figure 4 indicated lower TEWL values for African test subjects when compared to Caucasian test subjects. There were no significant differences for TEWL between Caucasian test subjects' experimental and control hands with the application of Gloves In A Bottle™ or Reinol™. Although along with the experimental values of Table 5 and Figure 7 it is evident that TEWL values decreased. From Figure 7 it can be noted that the percentage change in TEWL of the experimental hand was lower than the percentage change of the control hand which indicates a positive effect on barrier function. Therefore, Travabon™ showed an advantage on the skin barrier function.

For the African test subjects there were a significant differences between the experimental and control hands with the application of Gloves In A Bottle™ and Reinol™ ($p < 0.0003$) between experimental hands and control hands. Travabon™ was the only barrier cream where significant differences could be seen between the experimental and control hands ($p < 0.0001$). Berardesca and Maibach (2003) stated that *in vitro* measurements of TEWL were higher for African than Caucasian skin, and higher *in vivo* TEWL was measured for African skin while other results indicated no ethnic difference in TEWL. The study is in contrast with the literature as TEWL values were lower in African test subjects than Caucasian test subjects as shown in Figure 7. In Figure 10 TEWL values decreased at the back of hand, forearm, palm and wrist with the application Reinol™ and Travabon™, whereas Gloves In A Bottle™ showed constant TEWL values. TEWL increases with the thickness of the stratum corneum especially on the palms and soles; the increase in thickness of the stratum corneum is compensated with a corresponding increase in diffusivity (Farinelli and Berardesca, 2006) but in this study after the barrier cream was applied on the palms TEWL values decreased. A decrease could indicate partial occlusion of skin's surface and moisture retention from a topically applied product (Hauser, 2012).

pH

An optimal pH is required to activate lipid enzymes that are responsible for processing secreted lamellar bodies and is, therefore, important for the formation of the skin barrier (Feingold, 2007). From Table 6 it can be seen that the test subjects had high pH values before the barrier creams were applied. Gloves In A Bottle™ increased the skin pH although not enough to change the interpretation, Reinol™ increased and decreased skin pH in some areas and Travabon™ caused a slight decrease in pH although not enough to change the interpretation. The mild acidity of the skin's surface helps to maintain the strength and cohesiveness of the skin. The lipid organisation and lipid metabolism in the stratum corneum requires an acidic pH (Rippke *et al.,* 2004). Barrier creams led to pH values with a normal range to very high pH values (toward 7) a high pH will take time to restore the skins acidic mantle which acts as defence mechanism of the skin (Mizra *et al.,* 2006; Rawlings, 2010).

Enzymes involved in skin barrier formation are pH-dependent enzymes and are active in an acidic milieu (Mizra *et al.,* 2006). Gloves In A Bottle™ caused the highest skin pH values in Caucasian and African test subjects' skin which caused the skin to be moderately neutral. Reinol's™ pH values were normal in the forearm of Caucasian test subjects and normal in the forearm and wrist of African test subjects. From Figure 2 it can be seen Gloves In A Bottle™ increase pH for the Caucasian test subjects from 2 – 8 hours, whereas Reinol™ decreased TEWL values and Travabon™ showed no significant differences. For the African test subjects Gloves In A Bottle™ also increase pH where Reinol™ showed consistent values and Travabon™ led to a decrease in pH values. In Figure 5 Gloves In A Bottle™ showed significant differences for Caucasian and African test subjects with an increase in mean values, Reinol™ had a more negative spread for Caucasian test subjects and a constant spread for African test subjects. Travabon™ decreased pH values for both Caucasian and African test subjects. Considering the overall variation in pH percentage changes as a result of all three barrier creams, they were significantly

different from each other between Caucasian and African test subjects as seen in Figure 2 and Figure 5. Skin pH condition for Caucasians showed an increase with the application of Gloves In A Bottle™ and a decrease in pH for Reinol™, whereas Travabon™ did not cause a change in pH over the 8 hour period.
In Figure 8 all three barrier creams were significantly different when comparing Caucasian and African test subjects' experimental and control hands. The results showed that barrier creams lead to significantly different pH values between Caucasian and African test subjects. Figure 8 also shows Gloves In A Bottle™ led to very high pH values for the experimental hands of the Caucasian and African test subjects, which are significantly higher than the control hands. Travabon™ increased skin pH for Caucasian and African test subjects. In Caucasian test subjects, Reinol™ decreased pH in the experimental hand in comparison with the control hand, but had no significant difference, whereas in African test subjects Reinol™ caused an increase in pH more than the control hand. Reinol™ was only significantly different between Caucasian experimental pH and African experimental and between Caucasian control pH and African control pH.

A study by Rawlings (2010) found that there were lower pH values in African tests subjects compared to Caucasian test subjects which is contradicting to this study showing African test subjects had higher baseline skin pH values and higher experimental pH values as seen in Figure 6. Reduced skin acidity will make the skin less cohesive (Fluhr *et al.,* 2001). The skin generates acid as it converts phospholipids into fatty acids, for the formation of the skin barrier. When this conversion is blocked it has a marked effect on the acidity as well as the skin's integrity and cohesiveness (Fluhr *et al.,* 2001). There are differences in the pH according to different areas on the body. In skin flexure areas such as the palms and wrist there will be a high sweat secretion that will increase skin pH (Öhman, 2006). Figure 11 indicates that the barrier creams affected the pH of the African test subjects the most. The palms are described as the larger touch surface of the hand that comes into contact with a variety of different substances (Westerman, 1999). Gloves In A Bottle™ increased pH on the palm for African test subjects and had a small positive effect on Caucasian test subjects. On the wrist Travabon™ decreased pH in African test subjects whereas the pH was increased in Caucasian test subjects.

Gloves In A Bottle™ increased skin pH, Reinol™ decreased pH of the forearm, palm and wrist for Caucasians and increased the values for African test subjects, whereas the wrist values elevated over time. Travabon™ decreased pH for African test subjects and for Caucasian test subjects results differed between increasing and decreasing values. It has to be considered that anatomical areas differ because skin surface composition is not uniform and hygiene habits could also have an influence on skin pH (Schmid-Wendtner and Korting, 2007).

Conclusion

Gloves In A Bottle™ increased stratum corneum hydration and skin surface pH, had no effect on TEWL, whereas Reinol™ increased stratum corneum hydration and decreased TEWL with no effects on pH. Travabon™ decreased TEWL and stratum corneum hydration and had no effect on skin surface pH. When the skin is dry, it shows an increased transepidermal water loss as well as enhanced irritability, and is permeable to irritants and allergens. The ideal barrier cream should be non-toxic non-irritating, non-greasy depending on the type of protection desired, it should be easy to apply and remove and still be economical. A barrier cream should provide protection with no side effects on the skin in terms of stratum corneum hydration, TEWL and skin surface pH. This study proved that barrier creams can be beneficial and attribute to the workplace in protecting workers although great care should be taken when selecting a barrier cream for different workplace situations. From the results the recommended barrier cream to use when considering barrier function would be Reinol™ because it improved the hydration state and did not have significant changes in TEWL and pH values.

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CHAPTER 4

CONCLUDING CHAPTER

4.1 Further discussion and final conclusion

The aim of this study was to determine the positive and possible negative effects of three types of skin barrier creams on skin barrier function. Three types of barrier creams were used for this study namely Gloves In A Bottle™ which is a new type of barrier cream distributed in South Africa and widely advertised whereas Travabon™ and Reinol Skingard™ are currently in use in the industry. The three parameters that were measured was stratum corneum hydration, TEWL and skin surface pH. Male test subjects of both Caucasian and African ethnicities took part in this study.

Occupational contact dermatitis affects workers that come into contact with hazardous substances in the workplace and barrier creams help reduce the risk of irritant contact dermatitis and allergic contact dermatitis. In industries where gloves cannot be worn barrier creams are a promising alternative, but a disadvantage is that it gives a false sense of protection to a worker. Different types of barrier creams are used in the industry against these hazardous substances which could penetrate the skin surface. For a barrier cream to be effective the proper and frequent application is required although there are no specific guidelines of adequate amounts of barrier cream that should be applied. In this study it was found that barrier creams do cover the skin for protection, although they affect the skin barrier differently in terms of stratum corneum hydration, TEWL and skin surface pH.

The hydration of the stratum corneum decreased with the use of Travabon™ in Caucasian and African tests subjects which caused dryness of the skin and without adequate hydration the barrier function is impaired and irritability is enhanced (Darlenski *et al.,* 2009). When a barrier cream is efficient it should increase hydration state as was shown by Gloves In A Bottle™ and Reinol™ (Barel and Clarys, 2006). The results proved that there is a significant difference in stratum corneum hydration between Caucasian test subjects and African test subjects as Caucasian test subjects had a higher baseline hydration state than African test subjects when comparing the effects of the three barrier creams. Travabon™ decreased the hydration state, while Gloves In A Bottle™ increased values from control to experimental and Reinol™ increased the hydration state the most.

Stratum corneum hydration also differed from the different anatomical areas, where the highest anatomical hydration state was seen at the Caucasian test subjects' palm and the lowest was seen at the African tests subjects' back of hands.

Gloves In A Bottle™ led to the most normal and healthy TEWL values for Caucasian and African test subjects. An increase in TEWL values will reflect damaged skin and impaired skin barrier (Levin and Maibach, 2005). Travabon™ and Reinol™ decreased TEWL values which show that the skin barrier was enhanced when using Travabon™ because a decrease in TEWL values could indicate the formation of a protective film on skin's surface (Hauser, 2012).

Gloves In A Bottle™ increased the skin surface pH in Caucasian and African test subjects, and an increased pH could be associated with an inflammatory skin disease (Feingold, 2007). Reinol™ and Travabon™ did not change pH values and the experimental values showed normal skin pH. Changes in skin surface pH are related to skin barrier protection, an optimal pH is required to crate the necessary environment for the processing of precursors to non-polar lipids for the formation of the stratum corneum (Mizra *et al*., 2006).

Gloves In A Bottle™ increased stratum corneum hydration and skin surface pH, but had no significant effect on pH, Reinol ™ increased stratum corneum hydration and decreased TEWL and did not change pH values. Travabon™ decreased TEWL and stratum corneum hydration and had no effect on skin surface pH. Based on these results the best barrier cream to use when considering barrier function would be Reinol™ because it improved the hydration state and did not have significant changes in TEWL and pH values. An increase in hydration will result in a healthy skin barrier.

This study showed that current barrier creams are effective although not perfect. It is necessary to develop a barrier cream that could provide more protection with positive effects on the underlying skin barrier in terms of stratum corneum hydration TEWL and skin surface pH. This study proved that barrier creams can be beneficial and contribute to the protecting of workers in the workplace.

4.2 The research objectives were:

The skin barrier function was determined by measuring stratum corneum hydration, transepidermal water loss (TEWL) and skin surface pH, when comparing the effects of three different types of barrier creams on skin barrier function. Caucasian and African skin were compared by determining the effects of barrier cream on skin barrier function. The effects of the three different barrier creams on four different anatomical areas of the arms and hands were measured. All three of the objectives were reached and showed how three different barrier creams affected the skin differently. It is evident in this study that after a barrier cream was applied that ethnic differences in stratum corneum hydration were significant for all three barrier creams. TEWL had low values for the Caucasian test subjects and the lowest values for African test subjects. Gloves In A Bottle™ increased skin pH, Reinol™ decreased pH values of the forearm and palm for Caucasians and increased the values for African test subjects, whereas the wrist values elevated over time. Travabon™ decreased pH values for the African test subjects and for the Caucasian test subjects results differed between increasing and decreasing values. The results showed that there were differences in Caucasian and African test subjects indicating that Caucasian test subjects had higher hydration values when compared to African test subjects, and the four different anatomical areas had different reactions in terms of stratum corneum hydration, TEWL and skin surface pH.

4.3 Research question

The research question stated: Does skin barrier cream have any negative effects on skin barrier function with regards to stratum corneum hydration, TEWL and skin surface pH and how will racial skin types, such as African and Caucasian, differ from each other in terms of barrier function?

The research question was answered that the long term use of barrier creams can be harmful as it can decrease stratum corneum hydration, increased TEWL and skin surface pH with the use of barrier creams such as Gloves In A Bottle™, Reinol™ and Travabon™ although all three barrier creams did not show negative effects.

These three parameters all contribute to the permeability of the skin barrier and if these parameters are altered beyond the normal range the barrier of the skin is impaired which could lead to a more permeable skin surface. Workers will be more at risk for dermal exposure and subsequent skin disease. Caucasians and African test subjects showed significant differences when the different barrier creams were applied as seen with the experimental and control hands and anatomical areas were compared. In Caucasian test subjects hydration and TEWL values were higher after application on certain anatomical areas than African test subjects, and skin pH values were higher in African test subjects when compared to Caucasian test subjects.

These results indicate that there were significant differences between Caucasian and African test subjects with the use of barrier creams, because of the baseline differences and the reaction to barrier creams showed different results. It should also be noted that Caucasian and African test subjects reacted differently to the different barrier creams, this should be taken into account when selecting a barrier cream in the workplace.

4.4 Challenges

- Recruitment of test subjects proved challenging in this study, negotiating recruitment strategies and securing participation of test subject's required different solutions every day.
- Finding male test subjects that did not smoke was challenging.
- Tests subjects are not always reliable, and sometimes did not show up for their measurement day.
- Some of the test-subjects complained about the whitish appearance of the different barrier creams on their arms.
- Weather conditions can influence temperature and humidity, therefore, on rainy days no measurements could be conducted.
- One of the barrier creams had an oil basis which disrupted the test subjects when they were working during the day, leaving an oil mark on paper and clothes.

4.5 Recommendations for future studies

Measuring the short term effects of stratum corneum hydration, TEWL and skin surface pH and their effects should be tested. Barrier creams usage in combination with gloves should be measured to see if gloves and barrier creams can be used together and what the effects will be on the skin. A study can be done under different workplace situations where barrier creams are currently in use to examine their function under real workplace conditions and using test subjects as controls. Different irritants can be tested on the skin along with the barrier creams that provide protection to specific irritants, to test barrier creams efficiency.

4.6 Recommendations for the use of barrier creams

This study proved that 5 ml barrier cream on each hand is enough to cover the arm, hand and fingers. Reapplying barrier cream every 2 hours proved efficient, because in some situations it seemed as if the barrier cream rubbed off. The two most popular barrier creams for the test subjects were Gloves in a bottle™ and Travabon™ because both barrier creams dried quickly on the skin. Gloves In A Bottle™ was preferred because it left the skin soft. Because the results showed significant differences in ethnicity between barrier creams, ethnic differences should be taken in account when choosing a barrier cream.

4.7 Skin protection programme

Barrier creams can provide effective protection in the workplace if they are applied sufficiently. Because it can be difficult to achieve, skin protection programmes can be used in the workplace to prevent occupational contact dermatitis (Funke, 2007; Pohrt, 2007). A skin protection programme should provide on-going information about when and how workers' hands should be protected to promote skin integrity. The introduction of skin protection programmes in workplaces is an important element in the prevention of occupational contact dermatitis.

A skin protection programme is a series of practical instructions about skin care aimed at a well-defined group of people. It may be directed at a certain occupation such as wet workers, mechanics, and hairdressers or at a certain workplace. It is necessary that the skin protection programme is an integrated part of an educational programme, which should provide information on healthy and diseased skin, lead to early recognition of skin symptoms, and give the employees prerequisites to understand evidence-based recommendations regarding skin protective procedures. Ideally, an educational programme should improve knowledge about skin care, followed by a change in behaviour in favour of skin protection and a decrease in clinical skin symptoms (Agner and Held, 2002).

Depending on the target group a skin protection programme should include the following points, before workers hands come into contact with irritants:

- Wash hands with lukewarm water and an unscented irritant free soap.
- Rinse hands thoroughly and pat hands dry.
- Choose the appropriate barrier cream.
- Apply the barrier cream at the right time.
- Apply the adequate amount of barrier cream and apply all over the skin without leaving gaps.
- Reapply regularly (2 hourly).
- Know the function of the skin and consequences of occupational skin diseases.
- Be able to identify risk factors for the skin at work and the effects of these risks on the skin.
- Know how barrier creams work and the correct way to apply them.
- Learn how to identify warning signs of skin diseases
- Take responsibility to keep skin healthy and regard skin protection as a necessity.

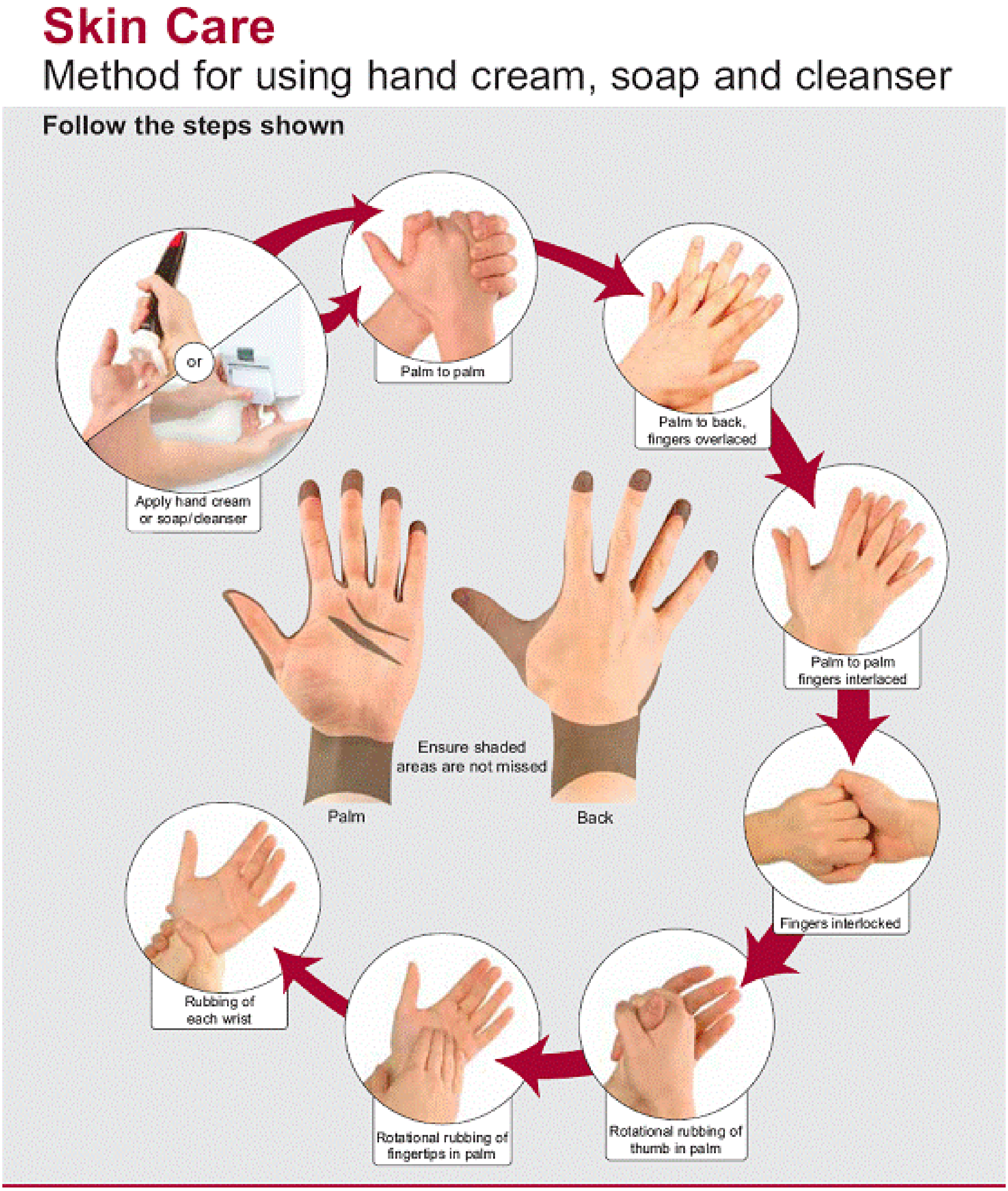

Figure 1: Illustrates the method for the correct application of any barrier cream and the washing regime (HSE, 2012).

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CHAPTER 5

APPENDIX

Dalgard skin questionnaire

During the last week, have you had any of the following complaints?

		No	Yes, a little	Yes, quite a lot	Yes, very much
1	Itchy skin				
2	Dry/sore skin				
3	Scaly skin				
4	Itchy rash on your hand				
5	Pimples				
6	Other rashes on your face				
7	Warts				
8	Troublesome sweating				
9	Loss of hair				
10	Other skin problems				
If yes when did skin problems start?					
During the last week					
During the last month					
1-6 months ago					
More than 6 months ago					