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REVIEW

Skin Health Connected to the Use of Absorbent Hygiene Products: A Review

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ABSTRACT

Over the past 50 years, absorbent hygiene products such as baby diapers and incontinence products have become essential features of modern day life. Through innovation and enhanced technology, their design, composition and performance have been dramatically upgraded from their early forms, and they have transformed the lives of millions of people, improving their quality of life. Skin health related to the use of absorbent hygiene products has accordingly also greatly improved. Still, the wearing of absorbent hygiene products will affect the skin, and for some users the changes in microclimate, mechanical interactions and the exposure to urine and faeces may result in irritant contact dermatitis, i.e. diaper dermatitis (DD) or incontinence-associated dermatitis (IAD). Babies with developing skin and the elderly with deteriorating skin functions who are the most frequent users of absorbent hygiene products are more vulnerable to the causal factors. Although irritant reactions are the most common, allergic contact dermatitis should be considered if a DD/IAD fails to improve by recommended actions. There is also a connection between IAD and pressure ulcer development of which it is important to be aware. A holistic approach of using high-quality absorbent hygiene products in combination with appropriate skin care will help maintaining good skin health.

Keywords: Absorbent hygiene product; Diaper dermatitis; Incontinence associated dermatitis; pH; Skin barrier; Skin health; Stratum corneum

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INTRODUCTION

The emergence of disposable absorbent hygiene products, for, e.g., babies and people suffering from incontinence, has transformed the lives of millions of people whether they are users of the products or people who care for them. The absorbent hygiene products contribute to improved quality of life by attributes of dryness, hygiene, leakage control, comfort, and skin health. Incontinence products have a significant positive impact on the quality of life of individuals suffering from incontinence, by offering security, comfort, discretion and odour control. They also enable users to maintain their sense of dignity and engender the confidence that allows them to leave their homes, work, take part in social activities and lead a full and satisfying life.

Absorbent hygiene products are worn in close contact with the skin and accordingly they interact with the skin. Urine and faeces, contained in the products, may also come in contact with, and interact with, the skin. The skin of a healthy adult is a good, protective barrier but repeated exposure to, e.g., urine, faeces and excessive moisture may weaken the skin barrier. The resulting skin irritation is called diaper dermatitis (DD) or incontinence-associated dermatitis (IAD). The young and old users of those products also have a skin that is under development or where many skin functions have deteriorated, increasing the demand on the absorbent hygiene products and the skin care in that region of the body, in order to minimize the negative skin impact.

This review article is based on previously conducted studies and does not involve any new studies of human or animal subjects performed by any of the authors.

PROGRESS IN PRODUCT DEVELOPMENT OF DISPOSABLE ABSORBENT HYGIENE PRODUCTS

The first disposable baby diaper was produced around the 1940s and was a product that consisted of squares of soft crepe paper folded into a rectangular shape and held in place by a plastic pant. Since then, there have been a number of improvements in design and function, and today's diapers are often incredibly effective as regards both absorption and dryness. The introduction of superabsorbent polymers in the absorbent disposable hygiene products in the middle of the 1980s was a very important milestone for improving the skin health of the users. The presence of the superabsorbent polymers in the absorbent hygiene product allow for better absorption of liquid, and since the polymers lock the liquid inside, the contact between liquid and skin is minimized, which results in a healthier skin [1–3].

Complete and prolonged occlusion of skin will with time result in a higher humidity, pH and microbial growth [4] in the area that is covered by the product. Therefore, the introduction of water-vapour-permeable materials (also called "breathable" materials) was yet another step in improving skin health for the users, helping to reduce the humidity in the microclimate [5, 6] and skin hydration [5]. As shown by Fig. 1, the frequency of diaper dermatitis in infants has accordingly decreased over the years, and it appears that better disposable diaper technologies have played a key role in the improvement of skin condition [7].

THE SKIN BARRIER

The main function of the skin is as a barrier between the body and the environment [8]. It serves to protect the body from hazardous external factors like chemicals and colonizing microorganisms, while at the same time keeping the internal system intact, thereby upholding the balanced and strictly controlled physiological conditions needed for life (i.e. water homeostasis).

The skin is composed of three distinct layers: the epidermis, dermis and subcutis. Epidermis is a multilayered self-renewing keratinized epithelium and is the part of the skin that is in contact with the external environment. The skin barrier function resides in the epidermis, or, to be more specific, in the stratum corneum (SC), the outermost part of epidermis. SC is normally 10–20 μm thick, but, despite its thinness, it is a structure with remarkable properties. It consists of 10–25 layers [9] of flat, partly overlapping keratin (protein)-filled cells: corneocytes, organized approximately in parallel to the skin surface, and surrounded by a highly organized lipid matrix [10, 11]. The structural arrangement of SC is often envisaged as a brick wall, where the corneocytes correspond to the bricks and the surrounding lipid matrix to the mortar [12].

The corneocytes are more or less impermeable for all penetrants, with water molecules as an exception [13]. The barrier capacity of the skin is therefore said to be a function of the molecular architecture of the lipid structure in the extracellular space of the SC [14]. The three

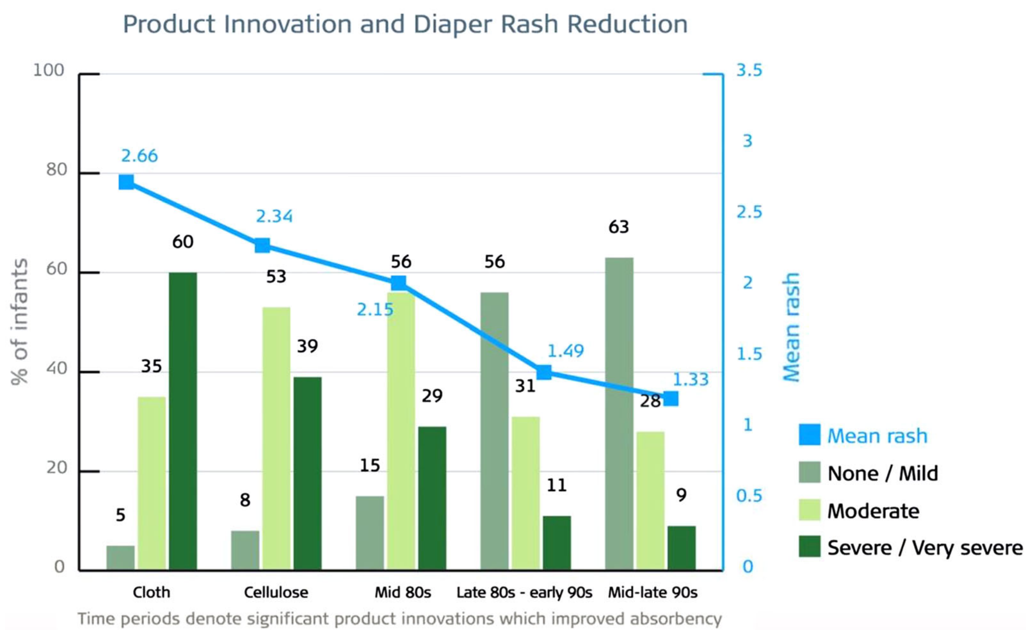

Fig. 1 Effect on frequency of diaper dermatitis from development of modern disposable diapers [7]

major lipid classes of the human SC are ceramides, free fatty acids and cholesterol, which are present in an almost equimolar ratio [15]. However, their precise molecular organization is still not solved, even if time and the development of new methodological approaches have taken the solution closer [8, 14, 16].

The structural organization of the corneocytes and the lipid matrix of SC are of utmost importance for the barrier function, but equally important is that the layer is renewed [17]. As mentioned earlier, epidermis is a self-renewing structure in which corneocytes are released from the skin surface in a continuous and controlled way, and this process (desquamation) is strictly balanced towards the production of new cells in the deepest part of viable epidermis in order to uphold the barrier function of the SC.

SKIN SURFACE PH

Stratum corneum pH is relatively acidic compared to the body's near neutral, internal environment. Skin surface pH varies between different body sites and between different persons, but ranges approximately between 4 and 6. Thus, there is a difference of 2–3 pH units, or a factor of 100–1000 in proton concentration, between the living part of the epidermis and the skin surface [18]. The acidic pH has been shown to be important for barrier homeostasis, SC integrity and cohesion [19], and pro-inflammatory cytokine signaling [20]. Several pH-dependent enzymes are involved in the formation of the SC barrier, especially the hydrophobic barrier lipids, as well as its destruction by desquamation. The enzymes involved in the synthesis of barrier lipids have their optima at relatively low pH, e.g. β-glucocerebrosidase, which is involved in the synthesis of the ceramides, has a pH optimum of 5.6. In contrast, the enzymes involved in the degradation of the skin barrier have their optima at a higher pH, e.g. alkaline ceramidase, responsible for the degradation of barrier lipids, has a pH optimum of 9 [18]. So, a raised skin pH will alter the homeostasis by increasing the activity of enzymes involved in the degradation of the skin barrier, and by decreasing the activity of enzymes involved in the synthesis and processing of the barrier lipids [21].

SC pH is also important for the skin's antimicrobial properties. The growth of the normal skin flora is optimal at acidic pH levels, whereas pathogenic bacteria, such as *S. aureus*, thrive at neutral pH levels [19]. In general, higher bacterial counts are retrieved from skin with alkaline pH values [22].

It has long been recognized that age is a factor which influences skin pH. Immediately after birth, skin surface pH is elevated compared to older children and adults. The pH decreases during the first days of life to about 5.5, and the pH value later in infancy resembles those of adults [18, 19]. At the other end of life, an increased skin surface pH and a reduced buffer capacity in skin of the elderly have been seen. An increased sensitivity to skin irritants, cleansing procedures and bacterial infections is a result of the reduced alkaline neutralization capacity in older individuals. The activity of alkaline ceramidase has been found to be higher in aged human skin, which could explain the ceramide deficiency observed in the elderly [18, 19].

DIAPER DERMATITIS AND INCONTINENCE-ASSOCIATED DERMATITIS

DD is one of the most common skin conditions in infants and it has been reviewed in a number of publications [23–26]. It is an irritant contact dermatitis (ICD), which is an inflammation of the skin in the area covered by the diaper. IAD is a similar condition affecting older, incontinent persons wearing absorbent incontinence products. IAD has also been described and reviewed in many publications [27–30]. In both conditions, the somewhat humid environment under the diaper/absorbent incontinence product makes the skin more susceptible to injury from exposure to irritants, such as urine and faeces, and by friction from the materials of the product. The prevalence of both DD and IAD has in several studies been seen to vary widely [26, 27, 31–33]. The great variation could be due to different nature of studies, the product used and to different study populations, e.g. in regard of age and urinary/faecal incontinence (for IAD).

The reason for the increased vulnerability of the skin in the diaper area is multi-factorial, where one factor often leads to, or is aggravated by, another [26, 28]. The occlusive environment created by the absorbent product (depending on, e.g., the breathability of the product) changes the microclimate close to the skin (higher humidity and temperature) which in turn affects the skin with a rise in humidity, pH and temperature. The skin also becomes affected mechanically by the product, and wet skin is more vulnerable to mechanical interaction. There may also be irritants, microorganisms and enzymes from urine and faeces which have a negative impact on the skin (Fig. 2). All these factors together break down the skin barrier and the skin responds with inflammation, through the release of cytokines (e.g. IL-1α) resulting in an immune response, giving the symptoms of dermatitis; erythema, oedema, itching and sometimes pain. Microorganisms play an important role in DD and, when the barrier is weakened microorganisms normally present in the perineum area, may give rise to infection (Table 1) [34].

In a study by Stamatas et al. [35], non-invasive in vivo methods were used to document biophysical skin parameters characterizing the conditions of DD. They found a significant increase in skin erythema and hydration and a significant impairment in the SC water barrier on DD-involved areas compared to non-compromised skin within and outside the diapered area. Skin pH was also significantly more alkaline on affected skin sites but also on non-lesional diapered skin compared to non-diapered control sites.

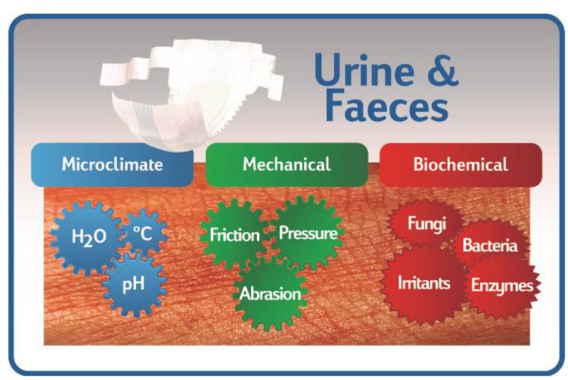

Fig. 2 External factors causing diaper dermatitis and incontinence-associated dermatitis

Table 1 The skin microflora in perineum [34]

Microorganism	Percentage
Coagulase-negative staphylococci	97
Lactobacilli	97
Corynebacterium spp.	92
Escherichia coli	47
Group B streptococci	38
Enterococci	34
α-Streptococci	32
Other Enterobacteriaceae	15
Candida albicans	15
Staphylococcus aureus	13

Managing skin wetness is the key factor in preventing dermatitis. The disrupted structure of the SC, resulting from overhydration, leads to enhanced permeability and increased susceptibility to irritants [36]. Water itself may also be a skin irritant. It has been shown that occlusion of skin with water-soaked patches can induce inflammation in the skin [37]. Overhydrated skin is also subjected to major mechanical effects, wet skin having a significantly higher frictional coefficient than dry skin [38]. At higher moisture levels, there is also an increased activity and growth of microorganisms [39].

An important method for the treatment of DD and IAD is to establish a healing environment for the skin [26, 27, 40]. This is accomplished by protecting the skin from further exposure to irritants and by minimizing the exposure to moisture. Evidently, harsh cleansing products and procedures should be avoided and barrier creams and zinc creams could be used to further protect the skin. If those measures fail, topical corticosteroids or antimicrobials may be used for more severe cases [26, 30].

ALLERGIC CONTACT DERMATITIS

Although most cases of dermatitis in the diaper region of adults and babies are of an irritant nature, there are also cases of allergic contact dermatitis (ACD) [41–45]. ACD is an inflammatory reaction in the skin that follows percutaneous absorption of haptens from the skin surface and recruitment of previously sensitized, antigen-specific T lymphocytes to the skin. ACD is the clinical manifestation of a contact allergy that one develops in contact with small, reactive chemicals. Lifelong sensitization will mount an immune response upon renewed contact with the allergen [46]. Groups of chemicals frequently causing contact allergy are listed in Table 2 [47].

The materials in an absorbent hygiene product mainly consist of polymeric compounds, which are too large to penetrate the skin and thus cannot cause contact allergies. When adding, e.g., skin care compounds to the product, it is important to bear in mind the safety aspects and the risk of introducing allergenic compounds. Fragrances, dyestuff and skin care ingredients are often small and sometimes reactive chemicals that potentially could induce contact allergy. Several cases of diaper dye dermatitis have been reported [48]. It is important to be extra careful when choosing materials and additives for these kinds of products, since they are worn on skin areas of high absorption (genitals), and the occlusion of the absorbent product further enhances skin penetration.

Table 2 Examples of compounds causing allergic contact dermatitis [47]

Examples of compounds frequently causing allergic contact dermatitis
Fragrances (e.g. eugenol, cinnamal)
Metal compounds (e.g. nickel and chromium)
Preservatives (e.g. MCI/MI[a], formaldehyde)
Topical drugs (e.g. local anaesthetics and antibiotics)
Rubber chemicals (e.g. thiuram compounds)
Plants (e.g. compositae plants)
Plastic- and glue chemicals (e.g. acrylics and epoxy compounds)
Textile- and hair dyes (e.g. PPD[b], toluene-2,5-diamine)

[a] *MCI/MI* Methylchloro- and methylisothiazolinone
[b] *PPD* Para-phenylenediamine

Until recently, ACD has been considered to be uncommon in children due to a belief that children are less exposed to contact allergens and that their immune system is not fully developed and therefore less susceptible [49–51]. ACD in children may be more prevalent than previously known, and patch testing in children with dermatitis has revealed positive reactions in 15–52% of subjects. Children as young as 6 months of age have been found to be sensitized, and case reports have documented ACD among children as young as 1 week of age [50, 52–55]. In old age, there is a decrease in cutaneous immune function which, e.g., leads to increased bacterial and fungal infections as well as cutaneous malignancies. There have been studies indicating that old subjects also have a reduced ability to mount ACD reactions in the skin [56]. The ability to become sensitized is also diminished in old age [57]. On the other hand, older persons are more likely to have become sensitized to more contact allergens than younger subjects [58].

As recommended by Smith et al. [59], if a diaper dermatitis (or IAD) fails to improve, by means of, e.g., frequent diaper changes and use of emollients, ACD should be considered and epicutaneous patch testing conducted. Importantly, not only the chemical constituents of the diaper/incontinence product but also skin care products and wipes used in the diaper area should be looked at. Suppliers should be asked to provide the different materials of interest to help in identifying the potential allergen(s).

THE VULNERABLE SKIN OF USERS OF ABSORBENT HYGIENE PRODUCTS

Besides the stress that is put on the skin from the exposure to urine and faeces, and the constant covering of the skin by an absorbent product, most of the users of absorbent hygiene products are either very young or old. Both young and aged skins are, in different ways, extra vulnerable to external insults. The absorbent hygiene products also cover mucosa, which lacks the barrier properties of keratinized skin.

THE BABY SKIN

The skin of the newborn is reported to be 40–60% thinner than adult skin, affecting all skin layers [60]. Precise measurements of skin layer thicknesses are elusive, but in a recent study by Stamatas and coworkers [61], the infant epidermis (3–24 months old) and the SC were reported to be 20% and 30% thinner, respectively, than found in adults. A thin SC in combination with an up to five times larger body-surface-to-weight ratio of the newborn [62, 63] increases the risk for skin damage, percutaneous infection and percutaneous toxicity from topically applied agents [62, 64].

The adaption of the skin barrier to the new conditions after birth, in the dry and more temperature-changing environment outside the uterus, was formerly thought to be ready shortly after birth [65–67]. Despite this, an increased tendency to develop ICD and ACD [68–70,] and an increased percutaneous absorption than for adults have been reported, which suggests that the skin barrier is still under development after birth [65, 71, 72]. In a study by Nikolovski et al. [73] it was shown that, even if infant SC seemed intact shortly after birth, the storage and transportation of water in infant SC (3—12 month of age) were different from adult skin at least during the first year of life. Infant SC has also been shown to be more hydrated and to contain less natural moisturizing factors than adult skin. They conclude that the infant skin barrier should not be looked at as being deficient at birth, but that there is an ongoing process of optimization that balances growth, thermoregulation, water barrier and protective functions which continues to at least 1 year of age. In a study by Mack et al. [74], it was found that water-holding and transport properties in the skin of children are different from adults up to the age of 4 years.

The corneocytes of the infant have been shown to be both smaller in size [61] and thicker in height than for the adult [75], which has been explained by the higher turnover rates of keratinocytes found in children under 1 year of age [61]. The increased cell turnover rates may result in an increased number of incompletely matured cells and thus negatively affect the functionality of the skin barrier [76]. Since infant SC is thinner [61], the number of corneocyte layers in the infant SC is also reduced [77], which may further explain the increased sensitivity and propensity of developing, e.g., DD.

AGED SKIN

Like all organs, skin ages with progressive morphologic and physiologic changes over time, which is the result of a genetic program combined with cumulative damage to genes and proteins. There are two types of skin aging: chronological, or intrinsic, skin aging, and photoaging, or extrinsic, skin aging. The former is related to intrinsic factors such as genetics and changes in the endocrine environment, and the latter is caused by environmental factors, with UV radiation and tobacco smoking being by far the most important [78]. Naturally, regarding aging of the skin in body areas relevant to the use of incontinence products, intrinsic skin aging is the dominant type.

Intrinsically aged skin is characterized by several morphological changes leading to deterioration of many skin functions [78, 79]. Thinning of the epidermis leads to increased vulnerability of the skin. A decrease in mitotic activity together with an increased duration of cell cycle and migration time results, e.g., in delayed wound healing. A slow replacement of barrier lipids, which are important for the skin barrier function, consequently results in a disturbed barrier function. Flattening of the dermo-epidermal junction, resulting in a smaller surface between the epidermis and the dermis, means less communication and reduced nutrient transfer between the layers. This also produces a higher sensitivity to mechanical damage. Reduction of dermis thickness due to a decrease number of fibroblasts, collagen fibers and elastic fibers lead to reduced strength and elasticity. The reduction of cutaneous microvasculature gives disturbed thermoregulation and supply of nutrients, while a reduction of nerve endings leads to disturbed sensory function. As mentioned earlier, in older humans, there is also a defective immunity in the skin. Clinically, intrinsically aged skin appears dry and pale with fine wrinkles and laxity [80].

It is also easy to understand the link between old age and the development of pressure ulcers. There is an association between IAD and pressure ulcers, with evidence that IAD increases the risk for pressure ulcer development [81]. Both moisture and friction/shear (in addition to ischemia, sensory perception, activity, mobility and nutrition) are risk factors for the development of pressure ulcers, and links IAD to pressure ulcer development. In addition, there is difficulty in differentiating superficial pressure ulcers from mild to moderate IAD, since they both present as erythema of intact skin. The underlying etiologic factors, however, differ where the erythema associated with a superficial pressure ulcer comes from an inflammatory response to ischemic damage in subdermal tissues, while in IAD the erythema results from an inflammatory response to irritant exposure restricted to the epidermis and dermis. The skin lesions are also present in slightly different locations: pressure ulcers over bony prominences, and IAD mostly in the perianal area, on inner thighs and on the buttocks. Another difference is that erythema associated with a pressure ulcer is non-blanchable [81]. If the precise cause is known, a successful therapy may more easily be selected.

MUCOSA

Mucosa is defined as a non-keratinized epithelium. The vulvar region in the genital area of females is a body location where both keratinized and non-keratinized skin co-exists. Generally, the outermost parts of the vulvar area consist of normal, keratinized skin, while the inner regions consist of non-keratinized epithelium. Between those areas, the epidermis is thinner and a gradual decrease in keratinization is seen [82]. Accordingly, the “border areas” are known to be more permeable to exogenous substances, more prone to irritant reactions, and to have a unique microbial ecology [83]. The mucous epithelium consists of loosely held, large, non-keratinized cells. In comparison to the well-organized and keratinized SC, the superficial layer of the mucosa also contains less packed layers and a less organized lipid structure [82]. This results in increased permeability (about 3–4 times higher than keratinized skin) and makes the skin more prone to irritant reactivity [83, 84].

The morphology and physiology of the vulva and vagina change over a lifetime, and the most prominent changes are connected to puberty, menstrual cycle, pregnancy and menopause [84]. Dermatitis in the perineum, the vulva and on the buttocks is a well-recognized and significant problem among incontinent elderly women [85].

SKIN CARE OF THE DIAPER AREA

Given the stress that is put on the skin under a diaper or an absorbent incontinence product, from urine and faeces as well as from the changes in the microclimate, it is easily understood that the skin in that region of the body is more vulnerable and needs extra care. This is even more evident in the developing skin of babies and in elderly skin with diminished functions. Cleansing products can interfere with the process of DD and IAD by the removal of skin contaminants and irritants. Cleansers should preferably contain mild surfactants (non-ionic) instead of soaps or more harsh surfactants (anionic) [86]. An emulsion cleanser, containing both a water phase and an oily, emollient phase, can offer even more advantages by mildly cleansing the skin but also caring for the skin, like a lotion. A no-rinse emulsion cleanser has been shown to cleanse the skin as effectively (in terms of the number of residual bacteria left on the skin) as soap and water [87]. Wipes can be used to cleanse the skin and are a convenient solution in some situations. Wipes (free from alcohol, fragrance, essential oils and harsh detergents) have been shown to be equivalent in terms of mildness to the skin compared to cleansing with water and cotton wool [88], and might therefore be a good alternative. Kottner et al. [89] has recently systematically reviewed the existing evidence for the effectiveness of skin care interventions for promoting and maintaining skin integrity and skin barrier function in the aged. The findings in that review were limited due to design and reporting weaknesses of the original studies. It could, however, be found that the use of emollient soap, non-detergent no-rinse cleansers and cleansers containing low-irritating surfactants showed skin-protecting effects compared to standard care. The skin-protecting effects might be enhanced when emollients and/or barrier products are additionally applied.

For babies, water and a washcloth are sufficient in most situations, but appropriately formulated cleansers could also be used. Emollients could be used if needed to maintain or enhance skin barrier function [90, 91].

For all wearers of absorbent hygiene products, a holistic approach of using high-quality absorbent hygiene products in combination with appropriate skin care will help to maintain good skin health.

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Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not involve any new studies of human or animal subjects performed by any of the authors.

Data Availability. Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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