Pediatric Dermatology Vol. 27 No. 1 1–8, 2010

Effect of Standardized Skin Care Regimens on Neonatal Skin Barrier Function in Different Body Areas

Natalie Garcia Bartels, M.D.,* Ramona Scheufele, M.Sc.,† Franziska Prosch, M.D.,* Tania Schink, Ph.D.,† Hans Proquitté, M.D.,‡ Roland R. Wauer, Ph.D., M.D.,‡ and Ulrike Blume-Peytavi, Ph.D., M.D.*

**Department of Dermatology and Allergy, Clinical Research Center for Hair and Skin Science, †Department of Medical Statistics and Clinical Epidemiology, ‡Clinic for Neonatology CCM, Charité-Universitätsmedizin Berlin, Berlin, Germany*

Abstract: **The effect of topical skin care products on neonatal skin barrier during first 8 weeks of life has not been scientifically evaluated. In a prospective, randomized clinical study, we compared the influence of three skin care regimens to bathing with water on skin barrier function in newborns at four anatomic sites. A total of 64 healthy, full-term neonates (32 boys and 32 girls) aged <48 hours were randomly assigned to four groups receiving twice-weekly: WG, bathing with wash gel (n = 16); C, bathing and cream (n = 16); WG + C, bathing with wash gel plus cream (n = 16); and B, bathing with water (n = 16). Transepidermal water loss, stratum corneum hydration, skin pH, sebum were measured on day 2, week 2, 4, 8 of life on front, abdomen, upper leg, and buttock. Skin condition was scored and microbiologic colonization was documented. After 8 weeks, group WG + C showed significantly lower transepidermal water loss on front, abdomen, and upper leg as well as higher stratum corneum hydration on front and abdomen compared with group B. Similarly, group C showed lower transepidermal water loss and higher stratum corneum hydration on these body regions. Group WG revealed significantly lower pH on all sites compared with group B at week 8. No differences in sebum level, microbiologic colonization and skin condition score were found. Skin care regimens did not harm physiologic neonatal skin barrier adaptation within the first 8 weeks of life. However, significant influence of skin care on barrier function was found in a regional specific fashion.**

Although full-term healthy neonates have an anatomically well-developed skin, epidermal barrier function is distinctly different between neonates and adults and is prone to dermatitis and infection (1–3). Appropriate skin care is of particular interest in neonates to maintain the natural adaptation of skin barrier (4). Skin

Address correspondence to Natalie Garcia Bartels, M.D., Clinical Research Center for Hair and Skin Science, Department of Dermatology and Allergy, Charité-Universitätsmedizin Berlin, Charitéplatz 1, 10117 Berlin, Germany, or e-mail: natalie.garcia-bartels@charite.de.

DOI: 10.1111/j.1525-1470.2009.01068.x

care regimens vary and are based on tradition in many countries (5–7). However, the influence of commercially available topical baby products on skin barrier function has not been scientifically investigated during the neonatal period. Some regimen may damage while others may maintain barrier function (8–10). A prospective study over the first 8 weeks of life appeared to be appropriate to assess dynamic changes of skin barrier comparing continuous skin care regimens (11,12). Neonatal skin barrier depends on different functional parameters and shows regional variability (13–15). We aimed to characterize neonatal barrier function using noninvasive techniques to evaluate transepidermal water loss (TEWL), stratum corneum hydration (SCH), skin-pH and sebum content in four anatomical regions. We hypothesized that twice-weekly bathing with commercially available baby wash gel and additional baby cream would not harm the natural adaptation of skin barrier in healthy newborns.

METHODS

Study Site and Population

A monocentric, prospective, randomized study was conducted from October 2006 to May 2007 in close cooperation between the Department of Dermatology, the Clinic for Neonatology CCM at Charité-Universitätsmedizin Berlin and the Department of Gynaecology of Clinic Dahme-Spreewald. A total of 284 full-term newborns were born at the Charité between October 2006 and May 2007, and 187 newborns between January and May 2007 at the Clinic Dahme-Spreewald. Inclusion criteria met all healthy full-term newborns with 37 completed weeks of gestation, aged ≤48 hours. Exclusion criteria included sepsis, serious congenital malformations, asphyxia, hydronephrosis, severe intracranial hemorrhage, immunodeficiency, pre-existing skin disease with eruptions covering more than 50% of body surface, relevant skin maceration or inflammation/irritation, urticaria, acute or chronic diseases with temperatures below 35°C or above 40°C. A total of 407 full-term neonates (86%) did not meet inclusion criteria, had exclusion criteria or were participating in another study. After having obtained written parental informed consent, 64 eligible full-term neonates were included. The trial had been approved by the local ethics committee of the Charité-Universitätsmedizin Berlin, Votum No. EA1/139/06.

Clinical Procedures

A total of 64 healthy, full-term neonates (32 girls, 32 boys) aged ≤48 hours were randomly assigned to four groups (each n = 16) receiving twice-weekly from day 7 until week 8 of life: group WG, bathing with pH 5.5 wash gel (Top To Toe Baby Gel Penaten®, Johnson & Johnson GmbH, Duesseldorf, Germany); group C, bathing with clear water and afterwards topical cream (Baby Caring Facial & Body Cream Penaten®, Johnson & Johnson GmbH, Duesseldorf, Germany); group WG + C, bathing with wash gel and topical cream; group B, bathing with clear water. All neonates were washed thee times with a cotton washcloth, moistened with water, until day 7.

Bathing lasted about 5 minutes using tap water at temperature 37–38°C, pH 7.9–8.2, hardness 13.4°dH (range: 7–25°dH). Diapers from Pampers® Baby Dry for Newborns were provided. Parents were instructed to avoid treating skin with any other skin care products, except of areas of skin trauma or diaper dermatitis: triclosan1%-cream, octenidin/phenoxyethanol-solution, zinc paste (optional with nystatin), to remove meconium: oil and vaseline.

Clinical Evaluations

Anatomical test areas for skin functional parameters and neonatal skin condition score (NSCS) were located at front (representing uncovered skin), abdomen, upper leg (mainly covered by clothes) and buttock (upper outer quadrant, mainly occluded). Transepidermal water loss, SCH, skin-pH and sebum were measured on day 2, week 2, 4 and 8 after birth in all groups, using non-invasive Multi Probe Adapter System MPA® (all Courage & Khazaka, Cologne, Germany): Tewameter® TM 300 was applied to skin for 30 seconds averaging data every 2 seconds, Corneometer® CM 825 and Skin-pH-Meter® pH 905 were applied for 2–3 seconds, Sebumeter® SM 815 data were received after 30 seconds. Room temperature and humidity were recorded with standard devices. No skin care was performed < 12 hours prior to measurements.

Skin conditions were evaluated using NSCS: dryness (1 = none, 2 = dry skin, 3 = very dry skin), erythema (1 = none, 2 ≤ 50% of surface, 3 ≥ 50% of surface), excoriation (1 = none, 2 = small, localized, 3 = extensive) (16). Microbiological colonization was documented by bacterial and candida swabs from the umbilical region at day 2 and week 4. Candida and bacteria were registered as positive or negative colonization, subspecies were not further identified.

Statistical Methods

All data in accordance with scaling and distribution were analyzed descriptively and expressed with box plots. In case of categorical data, Chi-square tests were performed.

For closer inspection of temporal courses in four groups (WG, C, WG + C, and B), a three-factorial analysis with repeated measurements was used. Analysis was performed for each test site separately and included main effect cream, wash gel and time, as well as their interactions. In cases, in which interactions between treatment and time showed significant effects, treatment groups were tested against group B at week 8 using Mann–Whitney *U*-Test. As test procedure for nonparametric analysis of variance, we used a method developed by Brunner, using statistic packets SAS V.9.1 (17). Otherwise program SPSS 16.0 (SSPS, Inc., Chicago, IL, USA) was utilized. All analyses resulted from explorative sense, p-value < 0.05 was considered as significant. Differences in room temperature and humidity between groups were tested using Kruskal–Wallis Test.

RESULTS

Participants

Baseline characteristics of 64 neonates in four groups were comparable (Table 1). No newborn was receiving medication or had clinical disturbances. In total, data of 64 newborns were collected until week 8; no drop-outs were noted.

Skin Functional Parameters After 8 Weeks

Postnatal adaptation of skin barrier was analyzed after 8 weeks in each skin care group in comparison with group B. Median TEWL was significantly lower on front, abdomen, and upper leg in group WG + C. No significant difference ($p = 0.224$) was found for TEWL in group WG + C on buttock area (Fig. 1). In group C, TEWL was significantly lower on all test areas at week 8 (Fig. 1). Comparing group WG and group B, no significant differences were found for median TEWL values on forehead, abdomen, upper leg, and buttock (all $p > 0.110$, Fig. 1).

Significantly higher SCH was found on forehead and abdomen in group WG + C and group C compared with group B (Fig. 2). Hydration values in group WG showed no significantly different median values compared with group B at week 8 (Fig. 2). An influence of room temperature and humidity on given results about skin functional parameters was statistically excluded at day 2 and week 8 in all groups.

Skin-pH was significantly lower in group WG compared with group B after 8 weeks at all anatomic test areas (Fig. 3). No significant differences regarding skin-pH were observed in group WG + C and in group C compared with group B on different body regions (Fig. 3).

Sebum level was independent of skin care regimen. All groups showed similar course of sebum until week 8. Median values are shown taken all 64 newborns together (Fig. 4). No sebum production could be found at upper leg (data not shown).

Skin Condition and Microbiologic Colonization

Skin care regimen did not significantly influence NSCS comparing day 2 and week 8 (Table 2). Therefore, correlation of NSCS with significant findings in skin functional parameters is unlikely. All groups showed mildly elevated NSCS at day 2 at all test sites. By contrast, at week 8 most test sites showed normal NSCS, except for

TABLE 1. *Baseline Characteristics of Enrolled Neonates in Skin Care Groups*

Characteristic	WG + C	WG	C	B
Female, No. (%)	8 (25)	8 (25)	8 (25)	8 (25)
Male, No. (%)	8 (25)	8 (25)	8 (25)	8 (25)
Caucasian, No. (%)	15 (94)	16 (100)	16 (100)	14 (88)
Non-Caucasian, No. (%)	1 (6)	0 (0)	0 (0)	2 (12)
Week of gestation, Mean (SD), week	40 (0.9)	39 (1.3)	40 (1)	40 (1.3)
Birth weight, Mean (SD), g	3371 (422)	3524 (500)	3480 (376)	3618 (387)
Birth length, Mean (SD), cm	52 (2)	51 (2)	51 (2)	52 (2)
Head circumference, Mean (SD), cm	35 (1.2)	35 (1.2)	35 (0.7)	36 (1.1)
APGAR normal, No. (%)	16 (100)	16 (100)	16 (100)	16 (100)
Eutroph, No. (%)	13 (81)	11 (69)	13 (81)	15 (94)
Hypotroph, No. (%)	3 (19)	2 (13)	2 (13)	0 (0)
Hypertroph, No. (%)	0 (0)	3 (19)	1 (6)	1 (6)
Vaginal delivery, No. (%)	12 (75)	12 (75)	11 (69)	9 (56)
Cesarean section, No. (%)	3 (19)	3 (19)	3 (19)	6 (38)
Forceps or vacuum, No. (%)	1 (6)	1 (6)	2 (13)	1 (6)
Primiparous, No. (%)	10 (63)	8 (50)	11 (69)	6 (38)
Maternal history of AD, No. (%)	0 (0)	1 (6)	0 (0)	2 (13)
Paternal history of AD, No. (%)	0 (0)	1 (6)	1 (6)	1 (6)

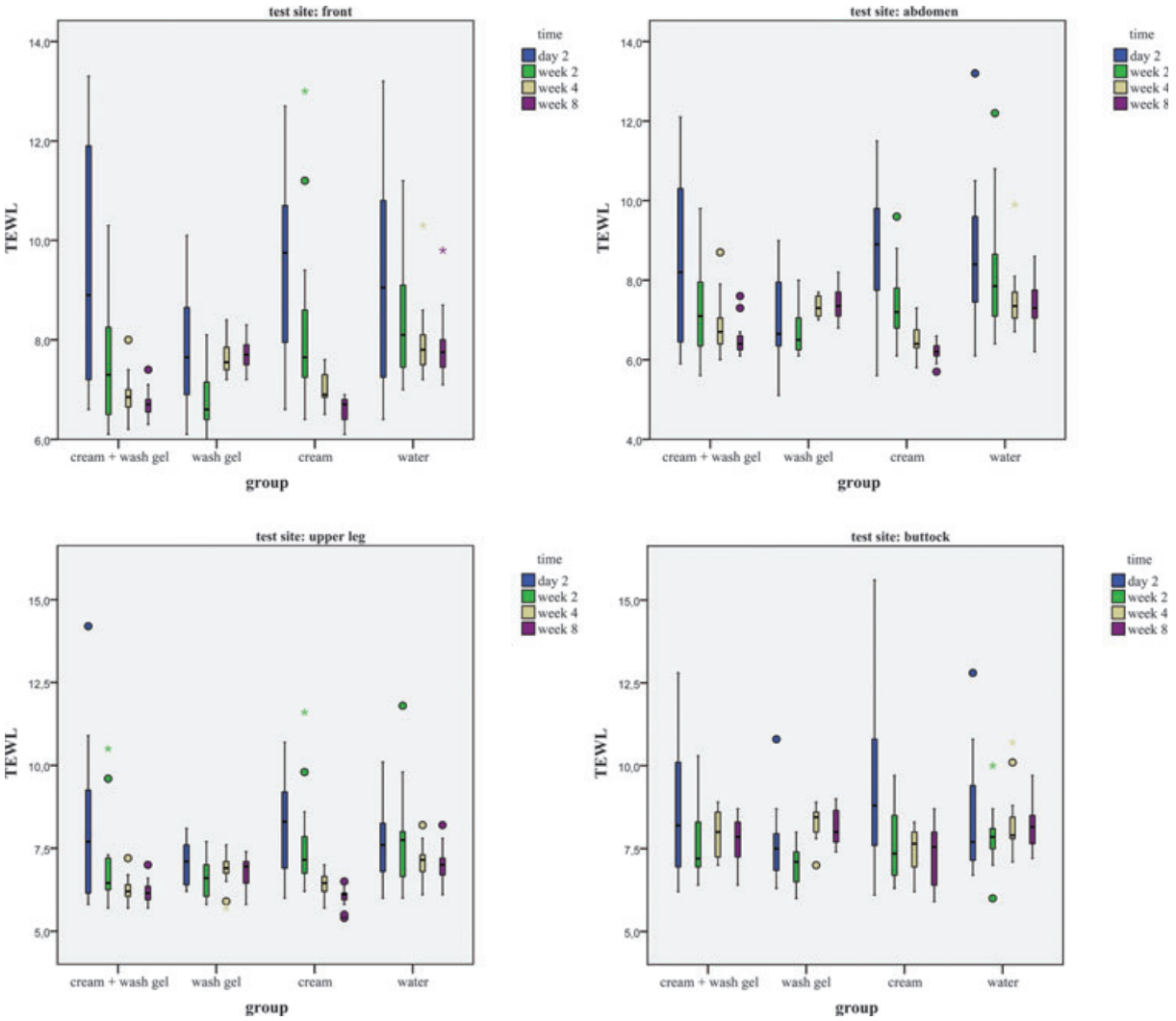

Figure 1. Postnatal course of TEWL in all groups. Median TEWL was significantly (all $p < 0.000$) lower on front 6.7 g/m^2/hour (range: 6.3–7.4), abdomen 6.4 g/m^2/hour (6.1–7.6), and upper leg 6.15 g/m^2/hour (5.7–7) in group WG + C (cream + wash gel) versus group B (water) at week 8. In group C, TEWL was significantly ($p < 0.000$) lower on forehead 6.7 g/m^2/hour (6.1–6.9), abdomen 6.2 g/m^2/hour (5.7–6.6), on upper leg 6.1 g/m^2/hour (5.4–6.5), and buttock 7.55 g/m^2/hour (5.9–8.7, $p = 0.011$) after 8 weeks. °/*outliers.

the front. The buttock test area was never affected by diaper dermatitis, which was perianal in all newborns. NSCS was not evaluated in the affected perianal area. Frequency of diaper dermatitis was statistically independent of skin care regimen (Table 3). Candida colonization was absent in all newborns at umbilicus until at week 4. Bacterial colonization without clinical signs of infection was present in $n = 31$ newborns at day 2, group WG + C $n = 8$, group WG $n = 7$, group C $n = 8$, and group B $n = 8$. Positive bacterial culture was found at week 4 in $n = 35$, group WG + C $n = 9$, group WG $n = 7$, group C $n = 10$, and group B $n = 9$. No significant difference was found comparing bacterial colonization and skin care group ($p > 0.75$). Percentage of neonates having a positive family history of maternal or paternal atopic dermatitis did not significantly differ in all groups ($p > 0.29$); group B had one neonate with positive paternal and maternal history of atopic dermatitis (AD, Table 1).

DISCUSSION

Skin barrier integrity is essential for infants, and skin care regimens should be age adapted on a scientific basis (18). Type and frequency of skin care regimen play a fundamental role in the model of environmental dosage effect

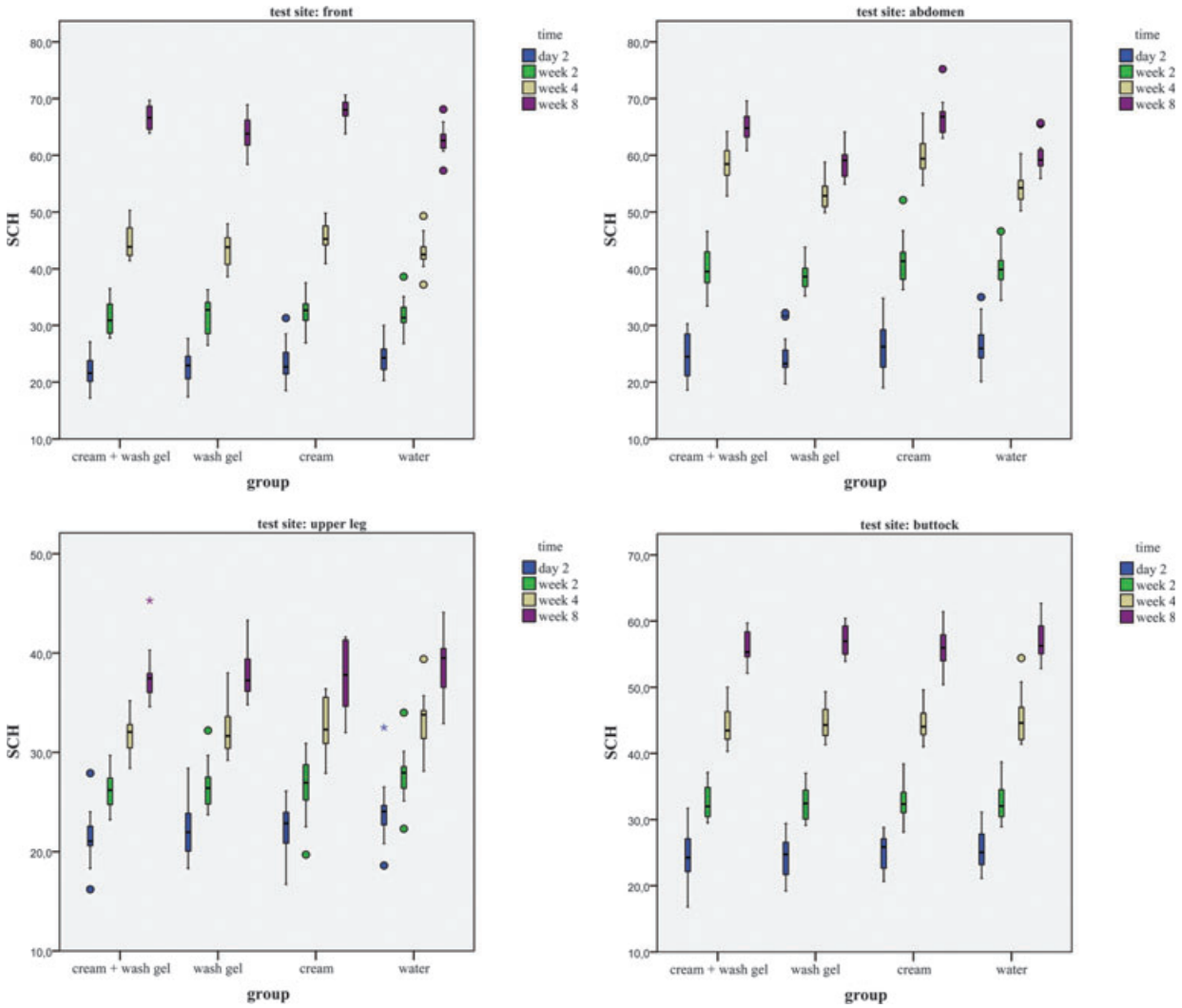

Figure 2. Postnatal course of SCH in all groups on different anatomic sites. Significantly (both $p < 0.000$) higher SCH was found on forehead 66.6 U (range: 63.9–69.7) and on abdomen 64.8 U (60.8–69.6) in group WG + C (cream + wash gel) compared with group B (water). Moreover, stratum corneum hydration was significantly (both $p < 0.000$) greater in group C (cream) on front 68 U (63.8–70.6) and abdomen 66.8 U (63–75.2). °/*outliers.

provoking skin barrier dysfunction in newborns (19). Nevertheless, limited basic research about neonatal skin barrier function in different body regions being influenced by topical care is available (15,20). In this study, anatomical test areas showed a different response to skin care regimens.

Transepidermal Water Loss

Predominantly, TEWL is established for evaluation of skin barrier effectiveness (21). In our study, TEWL was lower in newborns treated with twice-weekly bathing and application of cream on all anatomic test sites compared with bathing with water. Newborns, who additionally received wash gel, also presented lower TEWL compared with group B except for the buttock area. The course of TEWL was equal comparing bathing with and without wash gel (Fig. 1). In all groups, TEWL values were physiologic and comparable with those of healthy infants and adults (14).

Stratum Corneum Hydration

Skin maturation is influenced by the water content of the stratum corneum (22). In this study, increase of SCH on all test sites was proportionate to age and physiologic in all groups (12,15). Higher SCH was found on forehead and abdomen at week 8, if newborns received additional

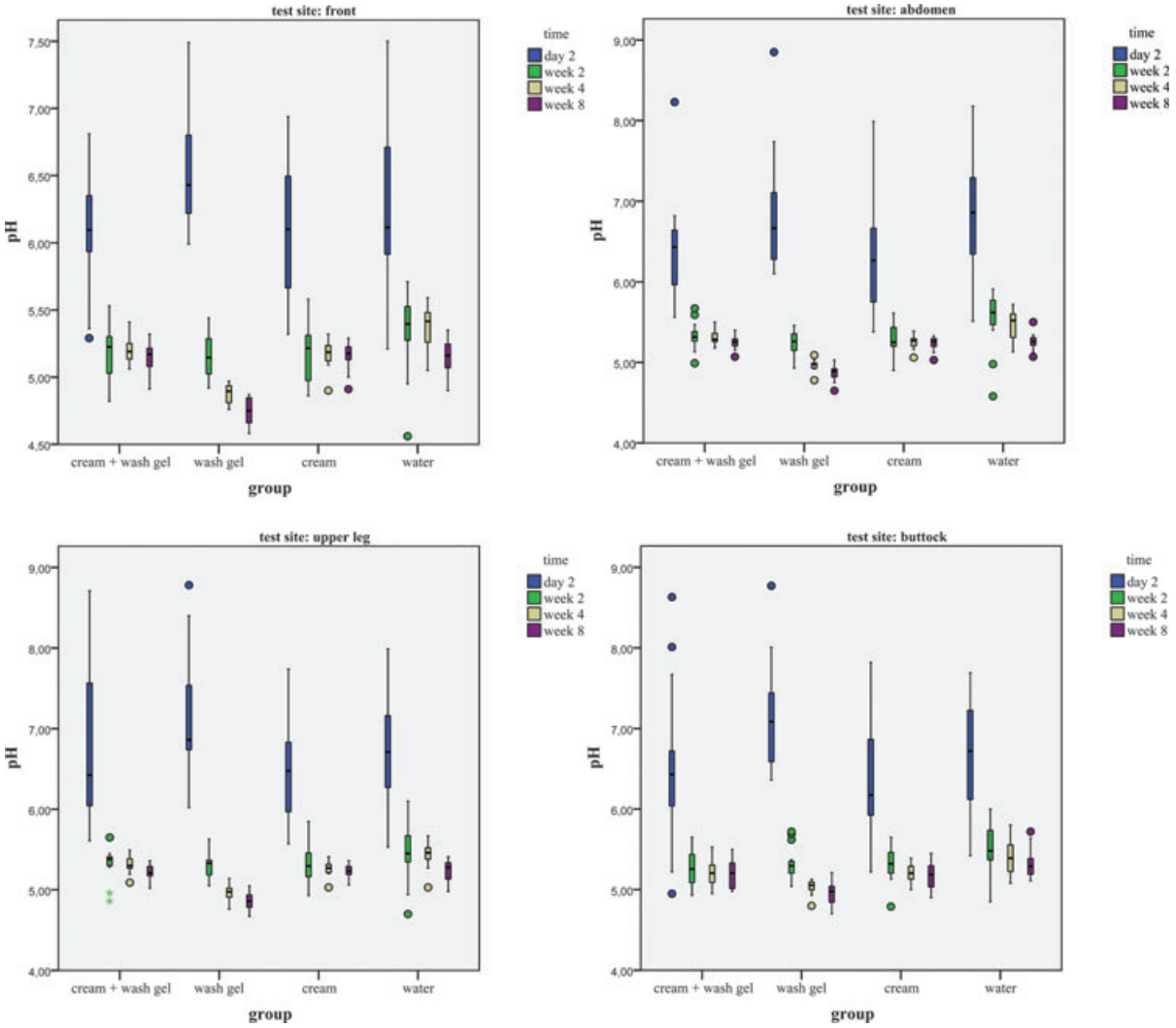

Figure 3. Postnatal course of pH on different anatomic sites. Skin-pH was significantly (all $p < 0.000$) lower in group WG (wash gel) compared with group B (water) after 8 weeks: forehead 4.75 pH units (range: 4.58–4.87), abdomen 4.89 pH units (4.65–5.03) upper leg 4.86 pH units (4.67–5.05), and buttock 4.98 pH units (4.7–5.21). °/*outliers.

cream (Fig. 2). Buttock and upper leg were not influenced by skin care regimen reflecting regional variability (15). Application of cream enhanced SCH on front and abdomen. Bathing with or without wash gel did not show any differences.

Influence of Skin Care Regimens on pH

At birth, skin-pH is near-neutral (pH 6.2–7.5), reaching adults' level (pH 5.4–5.9) after a few weeks (11). Soap, detergents, and pure water temporarily raise skin-pH in infants (23). An elevated skin surface pH is known in children with AD compared with controls (24). Our data show that the added baby wash gel or additional application of cream did not harm the acidification process of the epidermal barrier during the first 8 weeks of life (Fig. 3).

Course of Sebum

Little is known about the activity of sebaceous glands in neonates. Present investigations revealed similar values of sebum on forehead and upper leg in all groups, comparable with those reported in older infants (23). However, even pure water (pH 7.8–8.2) temporarily shifts sebum to lower values (23). In this study, sebum production remained stable during the study period. To demonstrate basic scientific data on the course of sebum in newborns, values are shown for all 64 newborns together (Fig. 4).

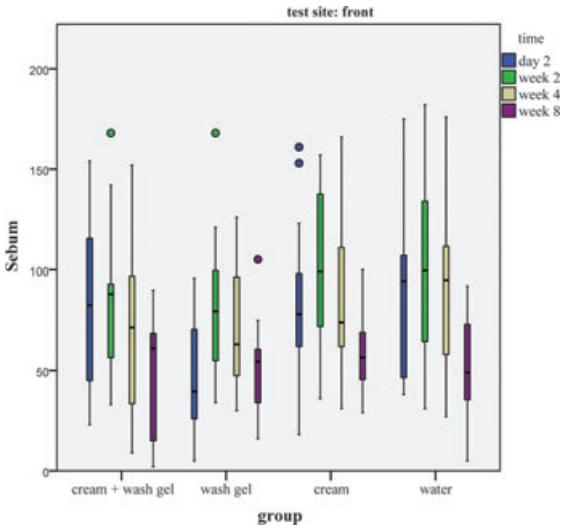

Figure 4. Sebum content evaluated in all groups together (n = 64) on day 2, week 2, 4, and 8 at forehead. All groups showed similar course of sebum until week 8. No influence of skin care regimen was found in sebum production at all sites. °/*outliers.

TABLE 2. *Neonatal Skin Condition Score (NSCS) at Day 2 and Week 8 at Tested Body Areas*

	NSCS-Score	WG + C (%)	WG (%)	C (%)	B (%)
Area day 2					
Front	3	6	6	9	5
	4	17	16	14	20
	5	2	3	2	0
Abdomen	3	6	6	8	6
	4	16	11	14	19
	5	3	8	3	0
Upper leg	3	16	10	11	9
	4	9	14	13	14
	5	0	2	2	2
Buttock	3	14	11	14	19
	4	11	14	11	6
	5	0	0	0	0
Area week 8					
Front	3	16	19	17	8
	4	9	6	8	16
	5	0	0	0	2
Abdomen	3	25	25	25	25
	4	0	0	0	0
	5	0	0	0	0
Upper leg	3	25	25	25	25
	4	0	0	0	0
	5	0	0	0	0
Buttock	3	24	25	21	22
	4	2	0	5	2
	5	0	0	0	0

Microbiologic Colonization and Skin Condition

In this study, different skin care regimens did not influence candida or bacterial colonization at the umbilical region as previously demonstrated (25). Frequency of diaper dermatitis was not influenced by skin care regimens. Skin condition was comparable in all groups reflected by a mildly elevated NSCS after birth, returning to normal values at most test sites at week 8 (Table 2). NSCS serves for detection of pathologic skin condition, but is not as sensitive as biophysical measurements to evaluate physiologic skin barrier function (16).

TABLE 3 *Frequency of Diaper Dermatitis in Different Groups*

Visit	WG + C n = 3	WG n = 0	C n = 4	B n = 2
Day 2	0	0	0	0
Week 2	0	0	2	0
Week 4	2	0	1	1
Week 8	1	0	2	1

The dynamic process of adaptation of skin barrier function was not harmed by tested skin care regimens in healthy full-term newborns. Although the use of cream and/or use of wash gel influenced skin functional parameters to some extent and seemed to have a mild positive effect on postnatal skin barrier adaptation compared with bathing with clear water, this effect was not statistically significant, and thus we cannot conclude from our study that any of the regimes we tested exerts a beneficial effect over the others on the physiologic adaptation or maturation of the newborn skin. A short alteration of TEWL or SCH by a single cleansing procedure has been previously shown (11,23). However, our data reflect a longer lasting effect of skin care measured 12 hours after last application. Lowest pH was found in newborns bathed with wash gel, additional use of cream revealed values equal to group B. Low SCH, high TEWL, and pH are well documented in patients with AD (24). Few neonates had positive maternal or paternal history of AD, which was statistically indifferent in all groups. Therefore, significant differences observed in study groups seemed to be independent of a different genetic background of studied individuals. However, one neonate had positive maternal and paternal history of AD. An influence on our data is unlikely, but should be ruled out in larger groups.

ACKNOWLEDGMENTS

The work of Franziska Prosch was supported by an unrestricted medical grant from Johnson & Johnson. The funders had no input regarding study design or conduct, data analysis or interpretation, manuscript preparation, or the decision to submit the results for publication. We thank Dr. Rüdiger Müller, Director of the Gynaecology Department at Clinic Dahme-Spreewald for his support to recruit newborns.

REFERENCES

1. Lund C, Kuller J, Lane A et al. Neonatal skin care: the scientific basis for practice. Neonatal Netw 1999;18:15–27.
2. Nikolovski J, Stamatas G, Kollias N et al. Barrier function and water-holding and transport properties of infant stratum corneum are different from adult and continue to develop through the first year of life. J Invest Dermatol 2008;128:1728–1736.
3. Taieb A. Hypothesis: from epidermal barrier dysfunction to atopic disorders. Contact Dermatitis 1999;41:177–180.
4. Darmstadt GL, Dinulos JG. Neonatal skin care. Pediatr Clin North Am 2000;47:757–782.
5. Hoath SB, Maibach HI. Neonatal skin: structure and function, 2nd ed. New York, Basel: Marcel Dekker, 2003.
6. Nako Y, Harigaya A, Tomomasa T et al. Effects of bathing immediately after birth on early neonatal adaptation and morbidity: a prospective randomized comparative study. Pediatr Int 2000;42:517–522.
7. Wong EY, Shairai JH, Garlock TJ et al. Adult proxy responses to a survey of children's dermal soil contact activities. J Expo Anal Environ Epidemiol 2000;10:509–517.
8. Glohr M, Wasik B, Gehring W et al. Cleansing, dehytrating, barrier-damaging and irritating hyperaemising effect of four detergent brands: comparative studies using standardized washing models. Skin Res Technol 2004;10:1–9.
9. Spergel JM, Paller AS. Atopic dermatitis and the atopic march. J Allergy Clin Immunol 2003;112:S118–S127.
10. Moore MM, Rifas-Shiman SL, Rich-Edwards JW et al. Perinatal predictors of atopic dermatitis occurring in the first six months of life. Pediatrics 2004;113:468–474.
11. Visscher MO, Chatterjee R, Ebel JP et al. Biomedical assessment and instrumental evaluation of healthy infant skin. Pediatr Dermatol 2002;19:473–481.
12. Hoeger PH, Enzmann C. Skin physiology of the neonate and young infant: a prospective study of functional skin parameters during early infants. Pediatr Dermatol 2002;19:256–262.
13. Harpin VA, Rutter N. Barrier properties of newborn skin. J Pediatr 1983;103:419–425.
14. Chiou YB, Blume-Peytavi U. Stratum corneum maturation. Skin Pharmacol Physiol 2004;17:57–66.
15. Yosipovitch G, Maayan-Metzger A, Merlob P et al. Skin barrier properties in different body areas in Neonates. J Pediatr 2000;106:105–108.
16. Lund CH, Osborne JW. Validity and reliability of the neonatal skin condition score. JOGNN 2004;33:320–327.
17. Brunner E, Domhof S, Langer F. Nonparametric analysis of longitudinal data in factorial experiments. New York, NY: Plenum Press, 2002.
18. Walker L, Downe S, Gomez L. Skin care in the well term newborn: two systematic reviews. Birth 2005;32:224–227.
19. Cork MJC, Murphy R, Carr J et al. The rising prevalence of atopic eczema and environmental trauma to the skin. Dermatol Pract 2002;10:22–26.
20. Behne MJ, Barry NP, Hanson KM et al. Neonatal development of the stratum corneum pH gradient: localization and mechanism leading to emergence of optimal barrier function. J Invest Dermatol 2003;120:998–1006.
21. Pinnagoda J, Tupker RA, Agner TA et al. Guidelines for transepidermal water loss (TEWL) measurements: a report from the Standardization Group of the European Society of Contact Dermatitis. Contact Dermatitis 1990;22:164–178.
22. Sato J, Yanai M, Hirao T et al. Water content and thickness of the stratum corneum contribute to skin surface morphology. Arch Dermatol Res 2000;292:412–417.
23. Gfatter R, Hackl P, Braun F. Effect of soap and detergents on skin surface pH, stratum corneum hydratation and fat content in infants. Dermatology 1997;195:258–262.
24. Eberlein-Konig B, Schafer T, Huss-Marp J et al. Skin surface pH, stratum corneum hydration, trans-epidermal water loss and skin roughness related to atopic eczema and skin dryness in a population of primary school children. Acta Derm Venereol 2000;80:188–191.
25. Bryanton J, Walsh D, Barrett M et al. Tub bathing versus traditional sponge bathing for the newborn. J Obstet Gynecol Neonatal Nurs 2004;33:704–712.