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Skin Care in Neonates and Infants: A Scoping Review

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Keywords
Care goal · Infant · Intervention · Neonate · Outcome · Product category · Scoping review · Skin care · Skin physiology

Abstract
Background: Skin care is a basic, daily activity performed by formal and informal caregivers from birth until end of life. Skin care activities are influenced by different factors, e.g., culture, knowledge, industrial developments and marketing activities. Therefore, various preferences, traditions, and behaviors exist worldwide including skin care of neonates and infants. The objective of this scoping review was to obtain an overview about the evidence of skin care activities in neonates and infants. Studies from 2010 were eligible if the population was (skin) healthy neonates and infants; if the concept was skin care interventions; and if the context was at home, in a community setting, in a pediatric outpatient service, or in a hospital. We searched for the literature via OVID in MEDLINE and Embase, in the Cochrane Library, in trial registries and for gray literature. ***Summary:*** We identified 42 studies since 2010, which examined four main skin care interventions: bathing, wiping, washing, and topical application of leave-on products. Details of interventions were often not reported, and if they were, they were not comparable. The four skin care interventions focused on 13 different care goals, mainly prevention of skin diseases, maintaining skin barrier function, and improving (skin) health. We evaluated effects of skin care interventions using 57 different outcome domains; 39 of 57 were skin-related and 18 were not. Mostly, laboratory or instrumental measurements were used. ***Key Messages:*** Our scoping review identified four skin care interventions with a broad heterogeneity of product categories and application details. Studies in skin care interventions should include all relevant information about product category and application details to ensure comparability of study results. This would be helpful in developing recommendations for formal and informal caregivers. We identified 13 skin care goals. "Maintaining healthy skin/skin barrier function/skin barrier integrity," "prevention of atopic dermatitis," "cleansing," and "improving skin barrier function" were most often allocated to skin care interventions. There is substantial variability regarding outcome domains in skin care research. Our results support the need of developing core outcome sets in the field of skin care in healthy skin, especially in this age-group of neonates and infants.

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Introduction

Skin care is a basic and daily activity performed by everyone, by formal and informal caregivers from birth until end of life [1, 2], and is considered as a "fundamental care element" [3]. Usually, skin care routines are not questioned until special skin health-related issues occur such as perceptions of itch or stinging or signs of dry or irritated skin. Skin care activities are influenced by culture, geographical region, availability of sanitary structures (e.g., public baths), knowledge, industrial developments and marketing activities of companies, and whether it is dependent or independent care. Therefore, various different preferences, traditions, and skin care behaviors exist worldwide [1]. This practice variability also includes neonates and infants [4].

Chronological age has an impact on the structure and function of the skin. Especially, the skin of neonates reveals differences compared to the adult skin. Immediately after birth, there is an adaption from the warm and humid environment in utero to the usually cooler and dryer environment that includes skin pH-lowering and production of water-binding natural moisturizing factors and an increase of the epidermal barrier antimicrobial function [5, 6]. At birth, the stratum corneum (SC) hydration is lower which changes in the first months of life [7]. Transepidermal water loss (TEWL) values indicate a competent basal permeability barrier function in neonates without cutaneous diseases, and pH values indicate an acidification in the first months of life [6]. Although the skin is rapidly maturing, the functional capacity and resistance to internal and external stressors or insults are lower compared to those in later periods in life [8]. Evora et al. [9] explored the relationship between the maturation of corneocytes and the mechanical resistance as one of the "most critical steps in the formation of an effective SC barrier." Interestingly, when the morphology of the corneocytes is perturbed, an impaired barrier function is observed, and some skin disorders may arise [9]. Besides not fully developed skin barrier function of neonates and infants [10], their skin has additionally lower mechanical resistance to damage due to thinner epidermis, dermis, and hypodermis with a flatter dermal-epidermal junction [11, 12]. Biochemical characteristics also show differences [11]. In summary, infant's skin integrity is fragile in the first year of life and undergoes maturation processes, thus requiring protection of skin integrity. Skin care interventions should maintain skin health and do no harm to fragile skin maturation.

Evidence summaries or best practice recommendations for skin care regimes in neonates and infants are available (e.g., [13–15]). However, most often, clinical trials, systematic reviews, or guidelines focus on special skin risks or disease in selected samples such as atopic dermatitis [16], diaper dermatitis (e.g., [17–19]), or the use of topical products such as oils [20, 21].

Evidence addressing other aspects of basic skin care procedures such as bathing frequencies, duration of bathing, and application of leave-on products on healthy skin is usually ignored. For example, bathing temperature is most often not fully described in studies, or details can be only found in single studies for special groups of babies [14]. Despite the available evidence, recommendations are frequently inconsistent and even sometimes contradictory. For example, the Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN) recommended in 2018 to bathe newborns once every couple of days [14], while NICE [22], in contrast, recommended daily bathing. Regarding leave-on products, AWHONN recommended to form a thick layer on the skin to prevent diaper dermatitis, whereas NICE recommended a thin layer on the skin [22].

Independent from intervention effects, skin care goals in adult care are also often implicit or unclear, questioning the purpose of interventions [1]. Whether this is also the case in skin care in neonates and infants has never been systematically reviewed.

Another major challenge in generating and summarizing evidence is outcome heterogeneity. For example, there is a substantial discrepancy between what is considered important by systematic review authors and trialists [23, 24]. Empirical evidence indicates a high number and diversity of outcomes used in skin care research in adult and old populations [25], but a synthesis of skin care outcomes used in neonate and infant research is not available.

Objective

The objective of this scoping review was to obtain an overview about the evidence of skin care activities and routines in neonates and infants with regard to the interventions, details of the procedures, their indications, and applied outcomes.

The review will answer the following research questions:

1. Which skin care interventions are described in neonates and infants with healthy skin up to 2 years? And how are they performed?

Table 1. Key elements of the scoping review

Population (P)	(Skin) healthy neonates and infants from birth up to 2 years
Concept (C)	Skin care regimes Topical application of leave-on products such as creams, lotions, and ointments Skin cleansing such as bathing, using wipes, and rinse-off products, preventive nappy care
Context (C)	At home, community, pediatric outpatient services, hospital

2. Which indications and skin care goals are described for which skin care intervention?
3. Which outcomes are measured and how?

Methods

Eligibility Criteria

Studies were considered eligible if they met the criteria in Table 1 according to the population, concept, and context scheme [26]. We searched for publications written in English or German. The literature search was restricted to the last decade from 2010 until May 2022. Systematic reviews, experimental studies such as randomized clinical trials, and clinical controlled trials were eligible as well as descriptive longitudinal comparative studies.

Information Sources

The search included references from 2010 until May 2022. Electronic searches were conducted in MEDLINE and Embase via OVID, Cinahl via EBSCO, CENTRAL, and clinicaltrials.gov. Searches for gray literature were performed in ProQuest and Social Science Open Access Repositorium; reference lists of the included articles after full-text screening were checked for additional studies.

Search

Search terms included MeSH terms in combination with free text keywords. The search was executed in July 2021. An update search was performed on May 13, 2022. The search strategy in Embase and MEDLINE is shown in online supplementary Table 4 (see www.karger.com/doi/10.1159/000529550 for all online suppl. material).

Selection of Sources of Evidence

Two independent reviewers (D.W., R.A.) screened titles and abstracts, and differences in results were discussed with a third reviewer (U.B.P.). Reference lists of included articles were checked for additional studies. Due to the iterative character of a scoping review, we decided not to include systematic reviews because of lacking details in the description of the study interventions [26].

Data Charting Process and Data Items

The data extraction form by Elm et al. 2019 was modified for scoping review purposes and included items such as population, study design, age of infants, outcomes (online suppl. Table 5). Two independent reviewers (D.W., R.A.) extracted the data and were cross-checked against each other. If necessary, for obtaining additional information, we contacted the authors. We included the original wording of the selected studies used by the authors describing skin care products and procedures.

Critical Appraisal of Individual Sources of Evidence

A risk of bias assessment was not conducted.

Synthesis of Results

A matrix was created mapping the indications (skin care goals) against the interventions. All outcome measurement instruments were listed and inductively assigned to outcome domains.

Results

Selection of Sources of Evidence

The electronic database searches in MEDLINE and Embase via OVID, Cinahl via EBSCO, CENTRAL, and clinicaltrials.gov resulted in 7,645 articles. Searches for gray literature in ProQuest and Social Science Open Access Repositorium resulted in one article. Figure 1 shows the Prisma-ScR-flow diagram of the study identification process, screening and eligibility. 394 articles were read in full-text and 42 were included.

Characteristics of Sources of Evidence

Details of included studies are described in online supplementary Table 6. The 42 included studies addressed four general skin care categories: bathing ($n = 16$), wiping ($n = 12$), washing ($n = 1$), and topical applications of leave-on products ($n = 30$) in different body areas. Most of the studies reported combinations of skin care interventions. Nineteen studies were funded by industry, 18 studies were funded by public organizations, and the authors themselves funded one study. Four studies provided no information on funding.

Synthesis of Results

Bathing

The age of the included infants varied from 1 day after birth until 2 years of age. Three studies evaluated the effects of plain water without any addition of products [7,

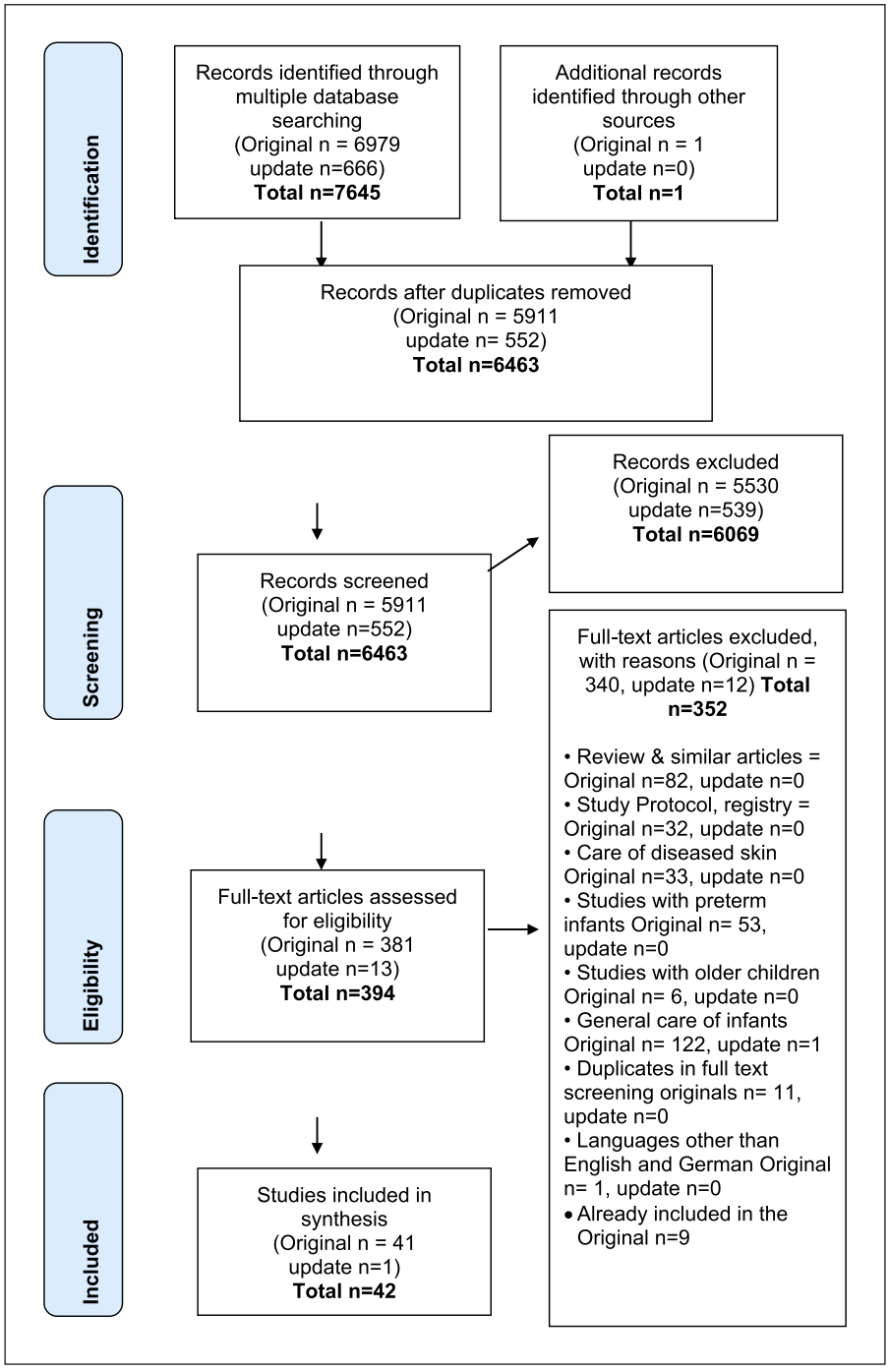

Fig. 1. Prisma-ScR-flow diagram of the study identification process, screening and eligibility.

27, 28]. The other studies reported the use of rinse-off products, i.e., "emulsified oil" added to the water or "bath/wash" or "cleanser" (e.g., [29–31]). Details such as the amount of product, length of bathing time, or water temperature were seldom reported [32], and bathing frequency per week ranged from daily to twice weekly.

Wiping

The age of the included infants varied from 2 days until 9 months of age. There was a difference between using wipes for the whole body or for the diaper area. The wipes were also not comparable between the studies including "water-soaked cotton wipes" [7, 33] or "wet wipes with emulsion" [34] based on nonwoven textile. Wipes for the

Table 2. Skin care goals and indications

Interventions	Cleansing	Maintaining healthy skin/ skin barrier function/skin barrier integrity	Prevention of skin problems	Supporting skin barrier adaptation/ maturation	Improving skin barrier function	Improving skin hydration	Prevention of atopic dermatitis	Prevention of food allergy	Prevention of allergic sensitization	Prevention of diaper dermatitis	Prevention of neonatal hyperbiliru-binemia	Improving neonatal health	Improving neonatal growth
Bathing													
Plain water	[27]	[7, 28]									[29]		
Rinse-off products													
"Emulsified oil," added to water							[30]						
"Shampoo"	[31]	[31, 55]	[34]										
"Bath/wash"	[32, 31, 27]	[31]											
"Cleanser/soap"	[47]	[47, 49, 37]	[34, 40]		[48, 40, 41]		[41, 54]	[54]					
"Bath gel"		[7]											
Wiping													
Mix product (leave-on and non-rinse-off)													
Body													
"Water-soaked cotton wipe"		[7]		[33]									
"Wet wipes with emulsion"			[34]										
Diaper area													
"Water-soaked cotton wipe"		[56, 49]		[57, 33]						[58]			
"Wet wipes with emulsion"	[59]	[59, 49, 28]	[34]	[57]		[59]				[60]			
Rinse-off product for body													
"Cleanser"	[35]	[35]		[33]									
Washing													
Face													
Plain water			[36]										
Rinse-off product "soap"			[36]										
Head													
Plain water			[36]										
Rinse-off product "soap"			[36]										
Topical application of leave-on products													
Body skin													
Emulsions													
"Moisturizer"		[36]	[40]		[40, 41]		[61, 41, 54]	[54]					
"Lotion"		[56, 47, 31, 49, 28, 37]				[62, 27]							
"Cream"		[7, 37]				[42]	[50, 43, 39, 51, 38, 63]		[51]				
Gel							[43, 38]						
Ointment							[43]						
Oil													
"Olive oil"					[44]						[29]		
"Sunflower seed oil"		[28, 53, 5]		[53]	[44]		[43]					[52]	[52]
"Mustard oil"		[45, 53, 5]		[53]	[45]								
"Almond oil"				[33]									
"Ayurvedic oil"													[46]

Table 2 (continued)

Interventions	Cleansing	Maintaining healthy skin/ skin barrier function/skin barrier integrity	Prevention of skin problems	Supporting skin barrier adaptation/ maturation	Improving skin barrier function	Improving skin hydration	Prevention of atopic dermatitis	Prevention of food allergy	Prevention of allergic sensitization	Prevention of diaper dermatitis	Prevention of neonatal hyperbiliru-binemia	Improving neonatal health	Improving neonatal growth
"Oil" (unspecified)			[34]										
Scalp skin													
"Oil" (unspecified)			[34]										
Face skin													
"Cream"							[64, 30]	[64]					
Diaper area													
"Cream"		[49]	[34]							[65, 66]			
"Powder"										[65]			
"Lotion"		[55]											
Total (*n*)	6	14	3	3	5	4	11	2	1	4	1	1	2

diaper area were more often examined (n = 9 studies) than for the whole body (n = 3 studies). In one study, cleanser applied to the infants' skin was rubbed to produce lather and then wiped dry with a soft cloth on [35].

Washing

Shimizu et al. (2021) examined washing and enrolled neonates 2 weeks after birth. The washing procedure was restricted to the neonates' face due to the intended evaluation of facial skin problems. The face washing procedure differed regarding the washing agent by "only water" to "usage of soap," and the washing methods differed also by using "hand," "gauze," or "hand and gauze" [36].

Topical Applications

In 4 studies, the included infants were up to 2 years old (e.g., [31, 37]). Most of the studies included newborns in the age from 1 day up to 4 weeks (e.g., [34, 38, 39]) when the intervention starts. All products were applied on the total body skin. "Emulsions" were described as "moisturizer," "lotion," or "cream" and evaluated in 21 studies (e.g., [40–42]); "gels" were examined in 2 studies [38, 43]; "ointment" was examined in 1 study [43]; and different kinds of natural oils ("olive oil," "sunflower seed oil," "mustard oil," "almond oil," "ayurvedic oil") were examined in 11 studies (e.g., [44–46]). Details of the amount of product were described in five studies (e.g., [32, 44]). The other studies did not report those details. The intervention's duration ranged from 4 up to 12 weeks. The application varied from at least once a day up to several times a day without specification.

Care Goals and Indications

Overall, 13 types of care goals/indications were identified: cleansing, maintaining healthy skin/ skin barrier function/skin barrier integrity, prevention of skin problems, supporting skin barrier adaptation/maturation, improving skin barrier function, improving skin hydration, prevention of atopic dermatitis, prevention of food allergy, prevention of allergic sensitization, prevention of diaper dermatitis, prevention of neonatal hyperbilirubinemia, improving neonatal health, and improving neonatal growth. The mapping of skin care interventions against care goals is shown in Table 2. The interventions in the category "bathing," having a bath or wash, were most often associated with "cleansing" (e.g., [27, 31]), and using "cleanser/soap" was most often associated with "maintaining healthy skin" (e.g., [37, 47]) or "improving skin barrier function" (e.g., [40, 48]). The category "wiping" refers either to the whole body or to the diaper area. "Wa-

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Table 3. Outcome domains

Outcome domains (what?)	Outcome measurement instruments/techniques (how?)	References
(1) Dryness	(1) Visual skin assessment questionnaire (present or not?)	Amer et al. 2017
	(2) Modified NSCS	Cooke et al. 2016 and Garcia-Bartels et al. 2011
	(3) NSCS	Lavender et al. 2011
	(4) Severity of dryness (4-point scale, with half-point scores used as necessary: 0 = none, 1 = mild, 2 = moderate, 3 = severe)	Duan et al. 2019
	(5) Severity of dryness (5-point scale; 0 = absence of symptoms, 5 = most severe symptoms)	Dizon et al. 2010, Okamoto et al. 2017, Summers 2019, and Stettler 2017
	(6) Severity of dryness (6-point scale; tolerance parameter scoring: 0 = none, 0.5 = barely perceptible, 1 = mild, 2 = moderate, 3 = marked, 4 = severe)	Gunt et al. 2018 and Visscher et al. 2021
	(7) Severity of dryness (6-point scale: 0–5, 0 = no visual compromise, 3 or 5 = greater damage)	Summers et al. 2018
	(8) Skin diary	Shimizu et al. 2021
	(9) Not defined	Zanardo et al. 2017
(2) Erythema	(1) Visual skin assessment questionnaire (present or not?)	Amer et al. 2017
	(2) Mexameter® Model MX18 probe (Courage & Khazaka electronic GmbH)	Lavender et al. 2012 and Cooke et al. 2016
	(3) NSCS	Garcia Bartels et al. 2011 and Lavender et al. 2011
	(4) Severity of erythema (4-point scale, with half-point scores used as necessary: 0 = none, 1 = mild, 2 = moderate, and 3 = severe)	Coret et al. 2014, Duan et al. 2019, Summers et al. 2018, and Visscher et al. 2021
	(5) Severity of erythema (5-point scale; 0 = absence of symptoms, 5 = the most severe symptoms)	Dizon et al. 2010, Iarkowski et al. 2013, Okamoto et al. 2017, Summers et al. 2019, and Stettler et al. 2017
	(6) Severity of erythema (6-point scale; 0 = none, 0.5 = barely perceptible, 1 = mild, 2 = moderate, 3 = marked, 4 = severe)	Gunt et al. 2018
	(7) Skin diary	Shimizu et al. 2021
	(8) Not defined	Zanardo et al. 2017
(3) Diaper dermatitis/diaper rash	(1) Severity of erythema (0 = no erythema, 1 = mild, 2 = moderate, 3 = severe, 4 = severe erythema with vesicles or eschar formations)	Chaithirayanon et al. 2016
	(2) SSDDS scale of 1–5 (1 = absence of redness or rash, 2 = some redness and a mild rash, 3 = the point at which broken skin and discomfort were evident, 4 and 5 = being more severe)	Mahayaty et al. 2021
	(3) Maternal observation	Price et al. 2021
	(4) Modified DRG (7-point scale; none = 0, severe = 3)	Garcia Bartels et al. 2014
	(5) Diaper Area Rash grading scale: type and severity of lesions (erythema, skin integrity, eruptions, edema) and extent and location (grade from 0 to 4)	Lavender et al. 2012

Table 3 (continued)

Outcome domains (what?)	Outcome measurement instruments/techniques (how?)	References
(4) Eczema/atopic dermatitis	(1) EASI	Chalmers et al. 2020 and Dissanayaka et al. 2019
	(2) POEM	Chalmers et al. 2020
	(3) UK Working Party diagnostic criteria for eczema	Chalmers et al. 2020, Lowe et al. 2018, McClanahan et al. 2019, and Skjerven et al. 2020
	(4) Modification of the UK Working Party's criteria (pruritic skin condition of at least 2 weeks' duration, visible flexural dermatitis and/or on the cheeks and extensor surfaces)	Horimukai et al. 2014
	(5) Criteria of the Japanese Dermatological Association	Dissanayaka et al. 2019
	(6) TARC	Dissanayaka et al. 2019
	(7) Diagnostic criteria of Hanifin and Rajka PLUS a specified time element	Simpson et al. 2010
	(8) Atopic Dermatitis Guidelines by Eichenfield et al. in 2014	Thitthiwong et al. 2020
	(9) Not defined	Glatz et al. 2018 and Simpson et al. 2014
(5) Peeling/flakiness	(1) Skin assessments: 0 = none; 1 = mild; 2 = moderate; 3 = severe	Coret et al. 2014 and Iarkowski et al. 2013
(6) Tactile roughness	(1) Skin assessments: 0 = none; 1 = mild; 2 = moderate; 3 = severe	Coret et al. 2014
	(2) Severity of roughness (4-point scale, with half-point scores used as necessary: 0 = none, 1 = mild, 2 = moderate, 3 = severe)	Duan et al. 2019
	(3) Severity of roughness (5-point scale [0–4], 0 [not present] = denoting the best condition, 4 [severe] = the worst)	Stettler et al. 2017
(7) Edema	(1) Skin assessments: 0 = none; 1 = mild; 2 = moderate; 3 = severe	Coret et al. 2014
	(2) Severity of edema: 5-point scale; 0 = absence of symptoms, 5 = the most severe symptoms	Dizon et al. 2010 and Stettler et al. 2017
	(3) Severity of edema: 6-point ordinal scale (tolerance parameter scoring: 0 = none, 0.5 = barely perceptible, 1 = mild, 2 = moderate, 3 = marked, 4 = severe)	Gunt et al. 2018
(8) Rash/irritation	(1) Skin assessments: 0 = none; 1 = mild; 2 = moderate; 3 = severe	Coret et al. 2014 and Summers et al. 2018
	(2) 4-point scale, with half-point scores used as necessary: 0 = none, 1 = mild, 2 = moderate, and 3 = severe	Duan et al. 2019 and Visscher et al. 2021
	(3) Severity of rash (5-point scale; 0 = absence of symptoms, 5 = the most severe symptoms)	Summers et al. 2019
(9) Scaling	(4) Not defined (1) Modified NSCS	Zanardo et al. 2017 Cooke et al. 2016
	(2) Severity of scaling: 5-point rating scale, 0 = absence of symptoms, 5 = the most severe symptoms	Dizon et al. 2010
	(3) NSCS	Lavender et al. 2011
(10) Skin roughness	(1) Digital images (Skin EvidenceTM Pro, INTUISKIN SA, Grenoble, France)	Duan et al. 2019
(11) Skin excoriation	(1) NSCS	Garcia Bartels et al. 2011
(12) Skin smoothness	(1) Neonatal skin globally scale with scores from 1 to 10	Horimukai et al. 2014

Table 3 (continued)

Outcome domains (what?)	Outcome measurement instruments/techniques (how?)	References
(13) Skin softness	(1) Neonatal skin globally scale with scores from 1 to 10	Horimukai et al. 2014
(14) Skin irritation	(1) Neonatal skin globally scale with scores from 1 to 10	Horimukai et al. 2014
(15) Papules	(1) 5-step grading scale, based on severity and size, none = 0, slight = 1, mild = 2, moderate = 3, severe = 4	Okamoto et al. 2017
(16) Maceration	(1) 5-step grading scale, based on severity and size, none = 0, slight = 1, mild = 2, moderate = 3, severe = 4	Okamoto et al. 2017
(17) Scratch mark	(1) 5-step grading scale, based on severity and size, none = 0, slight = 1, mild = 2, moderate = 3, severe = 4	Okamoto et al. 2017 and Stettler et al. 2017
(18) Crust	(1) 5-step grading scale, based on severity and size, none = 0, slight = 1, mild = 2, moderate = 3, severe = 4	Okamoto et al. 2017
(19) Erosion	(1) 5-step grading scale, based on severity and size, none = 0, slight = 1, mild = 2, moderate = 3, severe = 4	Okamoto et al. 2017
(20) Pigmentation	(1) 5-step grading scale, based on severity and size, none = 0, slight = 1, mild = 2, moderate = 3, severe = 4	Okamoto et al. 2017
(21) SC protein content	(1) Surface sample collection with 380 mm D-squame discs, CuDerm, Dallas, TX, USA)	Summers et al. 2018, Summers et al. 2019, and Visscher et al. 2021
	(1) SquameScan 850A; Heiland electronic, Wetzlar, Germany	Visscher et al. 2021
(22) Vesicles	(1) 5-point scale (0–4), 0 (not present) = the best condition, 4 (severe) = the worst	Stettler et al. 2017
(23) Any skin disorder	(1) Visual skin assessment questionnaire (present or not?)	Amer et al. 2017
(24) Overall skin condition	(1) 10-point scale for global/overall skin condition (1 = excellent to 10 = poor)	Coret et al. 2014 and Iarkowski et al. 2013
	(2) 5-point scale: with half-point scores used as necessary, with 0 = excellent, 1 = very good, 2 = good, 3 = fair, 4 = poor	Duan et al. 2019
	(3) NSCS	Garcia Bartels et al. 2010 and Yonezawa et al. 2018
	(4) Modified NSCS	Garcia Bartels et al. 2014
	(5) 7-point scale: good condition, almost good condition, occasional skin problems, dry skin, have skin problems frequently and not using steroids, have skin problems frequently and using steroids, and AD diagnosis	Yonezawa et al. 2019
	(6) Visual inspection for signs of compromised skin integrity	Shahunja et al. 2020
	(7) Not defined	Zanardo et al. 2017
(25) SCH/skin subsurface hydration and water content/cutaneous capacitance	(1) SCH with Corneometer® CM 825 Courage & Khazaka, Kȍln, Germany	Coret et al. 2014, Cooke et al. 2016, Duan et al. 2019, Garcia Bartels et al. 2010, Garcia Bartels et al. 2011, Garcia Bartels et al. 2012, Garcia Bartels et al. 2014, Glatz et al. 2018, Kanti et al. 2017, Lavender et al. 2011, Lavender et al. 2012, Lavender et al. 2013, Lowe et al. 2018, Okamoto et al. 2017, Shimizu et al. 2021, Simpson et al. 2010, Stettler et al. 2017, Yonezawa et al. 2018, and Majima et al. 2022
	(2) Moisture Meter, SC-5; Delfin Technologies	Horimukai et al. 2014
	(3) Soft Plus 5.5; Callegari SPA, Parma, Italy	Zanardo et al. 2017
(26) Skin moisture content	(1) Skin moisture content by conductance (Skicon 200, IBS Co., Japan)	Dizon et al. 2010
(27) Water distribution within the SC	(1) Confocal Raman spectroscopy	Stettler et al. 2017

Table 3 (continued)

Outcome domains (what?)	Outcome measurement instruments/techniques (how?)	References
(28) Structure of the lipid lamellae	(1) ATR-FTIR spectroscopy	Cooke et al. 2016
(29) TEWL	(1) Biox AquaFlux Model AF200	Cooke et al. 2016, Lavender et al. 2011, Lavender et al. 2012, and Lavender et al. 2013
	(2) VapoMeter, Delfin Technologies Finland	Dizon et al. 2010, Duan et al. 2019, Horimukai et al. 2014, Okamoto et al. 2017, Summers et al. 2018, Summers et al. 2019, Visscher et al. 2021, and Majima et al. 2022
	(3) Dermalab, Cortex	Glatz et al. 2018
	(4) Tewameter® TM 300 (Courage & Khazaka, Cologne, Germany)	Garcia Bartels et al. 2010, Garcia Bartels et al. 2011, Garcia Bartels et al. 2012, Garcia Bartels et al. 2014, Kanti et al. 2017, Lowe et al. 2018, Raboni et al. 2014, Shahunja et al. 2020, Shimizu et al. 2021, Simpson et al. 2010, Yonezawa et al. 2019, and Yonezawa et al. 2018
(30) Skin surface pH	(1) Skin pH meter® Model PH905 (Courage & Khazaka electronic GmbH)	Cooke et al. 2016, Dizon et al. 2010, Duan et al. 2019, Garcia Bartels et al. 2010, Garcia Bartels et al. 2011, Garcia Bartels et al. 2012, Garcia Bartels et al. 2014, Horimukai et al. 2014, Kanti et al. 2017, Lavender et al. 2011, Lavender et al. 2012, Lavender et al. 2013, Lowe et al. 2018, Shimizu et al. 2021, Yonezawa et al. 2018, and Majima et al. 2022
	(2) pH meter Horiba, Kyoto, Japan	Okamoto et al. 2017
	(3) Flat electrode (SkinCheck, Hanna Instruments, Bedfordshire, UK)	Summers et al. 2018, Summers et al. 2019, and Visscher et al. 2021
	(4) Soft Plus 5.5; Callegari SPA, Parma, Italy	Zanardo et al. 2017
(31) Sebum	(1) Sebumeter® SM 815	Garcia Bartels et al. 2010, Garcia Bartels et al. 2011, Kanti et al. 2017, Lowe et al. 2018, Shimizu et al. 2021, and Yonezawa et al. 2018
(32) Elasticity	(1) Soft Plus 5.5; Callegari SPA, Parma, Italy	Zanardo et al. 2017
(33) Epidermal desquamation	(1) D-Squame®	Garcia Bartels et al. 2012
	(2) Severity Scale: 5-point scale (0–4), 0 (not present) = the best condition, 4 (severe) = the worst	Okamoto et al. 2017 and Stettler et al. 2017
(34) Epidermal IL-1a	(1) IL-1a, picograms permicrogram of total protein loading on the tapes (pg/IL-1a/lg TP)	Garcia Bartels et al. 2012 and Garcia Bartels et al. 2014
(35) Skin bilirubin level	(1) Jaundice Meter China 800 (jk) device	Dehghani et al. 2019
(36) Skin oxyhemoglobin	(1) Diffuse reflectance spectroscopy (Ocean Optics, USA)	Dizon et al. 2010
(37) Skin deoxyhemoglobin	(1) Diffuse reflectance spectroscopy (Ocean Optics, USA)	Dizon et al. 2010
(38) Microbiological colonization	(1) Bacterial and candida swabs	Garcia Bartels et al. 2010 and Garcia Bartels et al. 2012
	(2) Skin samples with flocked swab (Catch-All™ Sample Collection Swab, Epicentre, Madison, WI)	Glatz et al. 2018
	(3) Not defined	Horimukai et al. 2014 and Lavender et al. 2012
(39) Warm sensation	(1) 5-point scale (0–4) as for clinical scoring	Stettler et al. 2017
(40) Infection	(1) Visual skin assessment questionnaire (present or not?)	Amer et al. 2017

Table 3 (continued)

Outcome domains (what?)	Outcome measurement instruments/techniques (how?)	References
(41) Nosocomial infection	(1) Nosocomial infections identified as the appearance of any new sign of infection during the hospital stay that was not present at admission or not present during the preceding 48 h of hospital stay	Shahunja et al. 2020
(42) Systematic inflammation	(1) CRP	Shahunja et al. 2020
(43) Time to recovery from acute illness	(1) Mean time (days) to recovery from the acute phase based on improvement in mental state, normalization of vital signs, re-establishment of oral feeding, and resolution of all acute illnesses	Shahunja et al. 2020
(44) Adverse effect/event/safety	(1) Visual skin assessment questionnaire (present or not?)	Amer et al. 2017, Lowe et al. 2018, McClanahan et al. 2019, Simpson et al. 2010, and Simpson et al. 2014
	(2) The presence or absence of an adverse event on the whole body	Okamoto et al. 2017 and Gupta et al. 2015
(45) Consumer satisfaction	(1) Diary (for comments or any observations and reactions with the use of the test product)	Dizon et al. 2010
	(2) Questionnaire (consumer perception of the efficacy and side effect (irritation) of the product)	Dizon et al. 2010
(46) Allergic sensitization (food allergy)	(1) Sensitization to food and/or inhalant allergens (total and allergen-specific IgE levels in blood)	Dissanayaka et al. 2019 and Horimukai et al. 2014
	(2) Skin prick test	Lowe et al. 2018
	(3) Self-reported outcome	Yonezawa et al. 2019
(47) Allergic sensitization (asthma)	(1) Serum levels of allergen-specific IgE	Horimukai et al. 2014
	(2) Skin prick test	Lowe et al. 2018
	(3) Self-reported outcome	Yonezawa et al. 2019
(48) Growth	(1) Anthropometrical measurements (weight, weight gain velocity, length gain velocity)	Gupta et al. 2015
	(2) Laboratory parameters (serum calcium, S. bone-specific alkaline phosphates, S. creatine phosphokinase, S. phosphorous, S. triglycerides)	Gupta et al. 2015
(49) Weight	(1) Digital weighing scale (SECA, Model 2781321009, Germany)	Shahunja et al. 2020
(50) Heat index	(1) Air temperature and relative humidity equation	Visscher et al. 2021
(51) Temperature	(1) Not defined	Visscher et al. 2021
	(2) Soft Plus 5.5; Callegari SPA, Parma, Italy	Zanardo et al. 2017
(52) Humidity	(1) Not defined	Visscher et al. 2021
(53) Anxiety/crying	(1) Not defined	Stettler et al. 2017
(54) Sleep patterns/sleeping quality	(1) VAS	Gupta et al. 2015
	(2) 5-point scale (0–4) as for clinical scoring	Stettler et al. 2017
(55) Adherence with intervention	(1) Not defined	Lowe et al. 2018, McClanahan et al. 2019, and Simpson et al. 2014
(56) Overall improvement	(1) Markedly improved, improved, slightly improved, unchanged, or aggravated	Okamoto et al. 2017

Table 3 (continued)

Outcome domains (what?)	Outcome measurement instruments/techniques (how?)	References
(57) Overall usefulness (of the therapy	(1) Usefulness: very useful, useful, slightly useful, useless, and harmful	Okamoto et al. 2017

NSCS, Neonatal Skin Condition Score; SSDDS, Scoring System for Diaper Dermatitis Scale; DRG, Diaper Rash Grade; EASI, Eczema area and severity index; POEM, patient-oriented eczema measure; TARC, thymus and activation-regulated chemokine score; IL-1a, interleukin-1a; VAS, Visual Analogue Scale; SCH, stratum corneum hydration.

ter-soaked cotton wipes" in the diaper area were associated with maintaining healthy skin as well as "wet wipes with emulsion" [7, 28]. In the category "topical application of leave-on products," "lotion" was mostly associated with "maintaining healthy skin" (e.g., [37, 47, 49]). "Cream" was mostly associated with "prevention of atopic dermatitis" (e.g., [39, 50, 51]). The application of "oil" had the widest heterogeneity of indications; except for "cleansing," all identified indications were associated with the application of "oil" (e.g., [5, 44, 52]).

Across all interventions, "maintaining healthy skin" was the most often named indication/care goals (e.g., [35, 49, 53]). The second most often described indication was "prevention of atopic dermatitis" to be achieved by "bathing" or the "topical application of leave-on products" (e.g., [30, 54]).

In addition to the abovementioned skin-specific indications, we identified two skin care intervention studies, focusing explicitly on the generally broad concept of "growth of children" as the care goal [40, 46]. However, in these studies, there was a mix between topical oil application on the skin and massage of the skin so that effects on the selected outcome were not clearly distinguishable.

Outcomes and Outcome Measurement Instruments

In total, 57 outcome domains were identified (Table 3). Thirty of the 57 outcome domains were only reported in one study, and 27 outcome domains were at least reported twice or more often. Thirty-nine outcome domains were skin-related outcomes, and 18 outcomes referred to systemic patterns.

Per outcome domain, high numbers of outcome measurement instruments were found. Erythema, dryness, and atopic dermatitis were the outcome domains measured with the most different measurement methods. The domain "dryness" was measured using 9 different approaches including different clinical scores. "Erythema" measurements included different clinical scales and instrumental measurements: one measuring device [44, 55], one visual skin assessment scale [34], three different clinical scales containing 4 to 6 items (e.g., [27, 31, 56]), and one instrument with 3 subscales (Neonatal Skin Condition Score [NSCS]) [48, 57] were used to measure the severity of skin erythema. Additionally, patient-reported outcome measurement was used by parents filled in a description of erythema in a skin diary [36].

The three outcome domains TEWL, SC hydration, and skin surface pH were the most often evaluated outcomes in the included studies; TEWL in 25 studies, skin surface pH in 21 studies, and SC hydration in 21 studies. The most often applied outcome measurement instruments regarding TEWL was the Tewameter® TM 300, Courage & Khazaka, Cologne, Germany (e.g., [7, 36, 51]), and VapoMeter, Delfin Technologies, Finland (e.g., [5, 35, 58]).

Discussion

Summary of Evidence

We systematically mapped the available evidence of skin care interventions, care goals, and outcomes in skin healthy neonates and infants. The broad intervention categories bathing, wiping, washing, and topical application of leave-on products were associated with 13 different indications/care goals, mainly prevention of skin diseases, maintaining skin barrier function, and improving (skin) health. In addition, an unexpectedly high number of outcomes was found, including various ways of outcome measurements.

Skin Care Interventions

Results of this scoping review are mainly based on randomized clinical trials. Although we classified skin care interventions into broad categories, the details of performed interventions were often not reported including the amounts of administered products, duration of bathing, or bathing temperature. The duration of the interventions was also heterogeneous and ranged from 4 days

up to 24 months. Interventions started from the day of birth up to several weeks of age.

The concept of "bathing" is one example of the known problem of confusing designations of topical preparations, e.g., product format in skin care [59, 60]. For example, "bath/washes," "cleansers/soaps," or "bath gels" contain surfactants and other ingredients with the primary purpose to remove unwanted substances from the skin surface. The concept of "gel" rather describes a product format instead of an aqueous cleansing solution and is misleading. In the category of leave-on products, different concepts were also identified, such as moisturizer, lotion, or cream. The concept "moisturizer" indicates a function of a product, whereas "lotion" and "cream" are product formats. Creams and lotions are emulsions (diphasic systems) containing two immiscible lipophilic (e.g., petrolatum, waxes, oils) and hydrophilic (e.g., water, alcohol) phases stabilized by an emulsifier system. Depending on the emulsifier system, an oil-in-water (o/w) or water-in-oil (w/o) product is created. The most prominent distinguishing feature between a cream and a lotion is their viscosity; creams are semisolid, while lotions are liquid and often pourable [1].

Another main result of the scoping review revealed a huge heterogeneity in the details of the skin care interventions, especially in the duration of skin care intervention as well as in the daily application scheme. If there is no clear regulation or instruction for applying the skin care products, there is a risk of adverse reactions because all these skin care products (bath/washes or cleansers/soaps or bath gels) for cleansing purposes may contain ingredients, of which some are potentially skin damaging. There is a huge body of evidence describing the damaging effects of surfactants in the adult population. Surfactants remove the physiological hydro-lipid film on the skin surface, they intercalate into the lipid bilayers of the SC, they damage the protein structures of the corneocytes, and finally they initiate a chemical mediator release eventually leading to inflammation [61–63]. Temporary or long-term elevation of the skin surface pH for instance due to repeated and prolonged exposures to alkaline soaps may lead to skin barrier impairments, irritation, and pathologic colonization [64]. There is a clear association between cleanser pH and the degree of skin irritation [65]. Mack Correa et al. [66] demonstrated that higher levels of oleic acid led to greater disruptions of the skin barrier. Topical product application may affect the skin physiology and increase the risk for adverse reactions [64, 67, 68]. Thus, adverse reactions of skin care interventions in neonates and infants should be avoided by reducing unnecessary exposure and choosing ingredients for care products that are suitable and especially selected for fragile neonatal and infant skin.

Skin Care Interventions and Care Goals

In total, 13 broad skin care goals were inductively developed. The categories "maintaining healthy skin/skin barrier function/skin barrier integrity," "prevention of atopic dermatitis," "cleansing," and "improving skin barrier function" were named most often and could be allocated to all identified interventions.

Based on the underlying mechanism of cleansers and ingredients, the obvious skin care goal seems to be "cleansing," but this was mentioned only six times. Instead of "cleansing," skin function-related care goals are in the center of interest such as "maintaining healthy skin/skin barrier function/skin barrier integrity," "prevention of atopic dermatitis," or "improving skin barrier function." By focusing the intervention "bathing," it is questionable whether, e.g., "bath/washes" or "cleansers/soaps" are able to "maintain skin barrier function" or to "prevent skin problems" in healthy skin. The nature of every cleansing agent is to remove unwanted substances from the skin surface, which is always inevitably associated with the removal of natural moisturizing factors or skin surface pH increases. Therefore, surfactants and other ingredients (such as humectants) help to compensate cleansing-induced damage but are primarily unable to "improve" the skin function.

Cooke et al. [4] showed in their systematic review that there was no evidence of any significant differences between tested wash products and water or tested baby wipes and water influencing skin physiological parameters. Fourteen included studies in our scoping review revealed no superiority of the tested skin care intervention influencing the skin integrity (e.g., [30, 38, 69]), similar to Cooke et al. (2018). That means that the interventions did not harm the skin, but at the same time, they also did not show any benefit for the skin.

The same may apply for leave-on products. Immediately after birth, there is the physiological skin maturation process. Although mentioned 3 times in our review, up until now, there is no evidence that any topical application of the investigated leave-on products was able to support the maturation process of healthy skin. On the other hand, if the skin barrier is disrupted, a targeted therapy for restoration of impaired barrier function is needed. For example, in 4 studies, authors aimed to achieve "improving skin hydration" [27, 42, 55, 70], albeit clinically, the treated skin of the included infants did not show signs of impairment. However, it remains open whether an in-

crease of SC hydration after topical product application contributes to care goals such as maintaining healthy skin/skin barrier function/skin barrier integrity.

Outcomes

In this scoping review, we identified a huge amount of outcome domains (n = 57), measured by clinical assessments, technical devices, and laboratory parameters. The outcome domain "erythema" was measured in up to 7 different clinical assessment techniques, e.g., with 4–6-point Likert scales by visual clinical inspection for severity of erythema or nominal scale with "erythema yes" or "erythema no" or the NSCS with three subscales. In the outcome domain "dryness," a technical assessment procedure was identified besides various clinical assessment instruments. This kind of heterogeneity in measurement methods may result in difficulties to meaningfully compare the results generated by different sources. The efficiency of these different methods in assessing the status of skin should be examined further to identify the best assessment instrument.

The most often evaluated outcomes in the included studies among all outcome domains were TEWL, SC hydration, and skin surface pH. These parameters represent the status of the skin barrier function. They were widely used skin measurement techniques performed in research facilities in standardized measurement conditions but were restricted in their use to trained professional staff. In the hospital setting as well in the home care setting, easy-to-use clinical assessment instruments should be harmonized for formal and informal caregivers.

Limitations

We might have missed studies in other languages than English or German. We included studies from the last 12 years. There might have been potential studies before 2010. The scoping review process allows refining the predefined schedule, and in our case, we decided not to include systematic reviews due to missing details in the descriptions of evaluated interventions. Due to the nature of a scoping review, we did not provide an effectiveness analysis of the identified skin care interventions, which might have been interesting for practice.

Conclusion

The scoping review identified 4 main skin care interventions with a broad heterogeneity of product categories and application details. Studies in skin care interventions should include all relevant information about product categories and application details to ensure comparability of study results. This would be helpful in developing recommendations for formal and informal caregivers.

Thirteen skin care goals were developed. "Maintaining healthy skin/skin barrier function/skin barrier integrity," "prevention of atopic dermatitis," "cleansing," and "improving skin barrier function" were most often allocated to the skin care interventions. Due to potential adverse reactions of skin care products, unnecessary exposure should be avoided.

There is substantial variability regarding outcome domains in skin care research. Our results support the need of developing a core outcome set in the field of skin care in healthy skin, especially in this age-group of neonates and infants. However, core outcome set development is a complex standardized process [24]. We consider this scoping review a useful starting point.

To make the selection of appropriate products and skin care procedures easier for formal and informal care givers, we recommend the development of a clear product terminology. Furthermore, adverse reactions of skin care interventions in neonates and infants should be avoided by reducing unnecessary exposure and choosing ingredients for care products that are suitable and especially selected for fragile neonatal and infant skin.

Conflict of Interest Statement

U.B.P. was a scientific member of the Board of the Dehaa Rossun Research Center, Kowloon, Hong Kong, China. D.W., R.A., and J.K.: none.

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Author Contributions

D.W.: conceptualization, methodology, software, formal analysis, investigation, writing – original draft, visualization, and project administration. R.A.: conceptualization, methodology, software, formal analysis, investigation, writing – original draft, writing – review and editing, and visualization. J.K.: conceptualization, methodology, validation, and writing – review and editing. U.B.P.: project administration, supervision, writing – review and editing, funding, and acquisition.

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