ORIGINAL ARTICLE SKIN AND EYE DISEASE

Functional textiles for atopic dermatitis: a systematic review and meta-analysis

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Abstract

Atopic dermatitis (AD) is a relapsing inflammatory skin disease with a considerable social and economic burden. Functional textiles may have antimicrobial and antipruritic properties and have been used as complementary treatment in AD. We aimed to assess their effectiveness and safety in this setting. We carried out a systematic review of three large biomedical databases. GRADE approach was used to rate the levels of evidence and grade of recommendation. Meta-analyses of comparable studies were carried out. Thirteen studies (eight randomized controlled trials and five observational studies) met the eligibility criteria. Interventions were limited to silk (six studies), silver-coated cotton (five studies), borage oil, and ethylene vinyl alcohol (EVOH) fiber (one study each). Silver textiles were associated with improvement in SCORAD (2 of 4), fewer symptoms, a lower need for rescue medication (1 of 2), no difference in quality of life, decreased *Staphyloccosus aureus* colonization (2 of 3), and improvement of trans-epidermal water loss (1 of 2), with no safety concerns. Silk textile use was associated with improvement in SCORAD and symptoms (2 of 4), with no differences in quality of life or need for rescue medication. With borage oil use only skin erythema showed improvement, and with EVOH fiber, an improvement in eczema severity was reported. Recommendation for the use of functional textiles in AD treatment is weak, supported by low quality of evidence regarding effectiveness in AD symptoms and severity, with no evidence of hazardous consequences with their use. More studies with better methodology and longer follow-up are needed.

Atopic dermatitis (AD) is a chronic, relapsing inflammatory skin disease with a considerable social and economic burden; it has an estimated prevalence of up to 20% in children and 2% in adults (1, 2). Its pathophysiology is complex and involves skin barrier defects and immunologic deregulation in genetically predisposed individuals (3–5). The skin of patients with AD is particularly susceptible to infection by different microorganisms. It is frequently colonized with *Staphylococcus* species capable of producing several virulence factors that contribute to the perpetuation of skin inflammation, even in normal-appearing skin (6). Disease management thus demands an integrated approach, aimed not only at diminishing pruritus, controlling skin inflammation, and ensuring skin hydration but also at regulating the skin microbiome (7, 8).

Textiles are considered an important part of AD management, and fabrics such as cotton and silk garments tend to reduce scratching and aid emollient absorption (9). With the development of nanotechnology, intelligent, or functional, textiles, which are designed to have beneficial effects on human health, have emerged (10). Such textiles have been used as adjuvants and antiseptic dressings in burns and wound healing with promising results (11, 12). In immunologically mediated skin diseases, and AD in particular, the focus has been to improve itch sensation, severity of lesions, and skin colonization by *S. aureus*.

Most of the studies of functional textiles in AD have investigated the use of specially treated long-sleeved shirts and pants in close contact with the skin. Cotton textiles can be functionalized with antiseptic silver salts (13, 14) or borage oil, which supplies fatty unsaturated acids to the skin barrier (15). Silk coated with specific antimicrobial chemical compounds and smooth ethylene vinyl alcohol (EVOH) fibers are also used to diminish physical stimuli applied to the skin (16). Nonetheless, contact between bioactive compounds in functional

textiles and a disrupted skin barrier raises safety concerns, although the few studies addressing the potential risks of sensitization, disturbance of the ecology of the skin, and toxic side effects have shown functional textiles to be safe and usable (17).

Although functional textiles may be a promising area in skin disease management, their role in AD has not yet been established. The aim of this study was to systematically review the efficacy and safety of these textiles in AD.

Methods

We selected published reports of randomized controlled trials (RCTs) and observational and case studies (with a cohort or case–control design) that compared or assessed the effects of functional textiles in patients of any age with a clinical diagnosis of atopic dermatitis; no restrictions were placed on disease severity or previous or current treatment.

The primary outcome was defined as changes in overall eczema severity, measured by the SCORing Atopic Dermatitis (SCORAD) index and other scales for evaluating AD severity (18). Secondary outcomes included changes in symptoms, quality of life, need for rescue medication, microbiologic skin flora composition, epidermal skin physiology, and safety.

Search strategy

In July 2012, electronic searches were undertaken in three large biomedical databases: the Cochrane Central Register of Controlled Trials, Scopus, and Medline. We used the following keywords (first group): 'atopic eczema dermatitis syndrome', 'atopic dermatitis', 'atopic eczema', coupled with (second group) 'textiles', 'fabrics', 'garments', 'clothes', and 'dressings'. *A priori* inclusion criteria limited retrieved articles to those assessing the use of textiles in individuals with AD. Subsequently, each study was evaluated to determine whether it met the entry criteria for the review. Hand searches of the reference lists of all pertinent reviews were performed and potentially relevant studies identified. Abstracts from relevant conferences were also searched. After the electronic literature searches, using the title, abstract, or both, two authors independently selected articles for full-text scrutiny. The authors agreed on a set of articles, which were retrieved and assessed to determine compliance with the entry criteria. Information regarding the following characteristics was extracted from each study: design (description of randomization, blinding, number of study centers, and number of study withdrawals); participants (sample size), mean age, age range of the population; intervention (type and study duration); and outcomes (type of analysis and outcomes analyzed). The results of comparable studies for a specific outcome were pooled using a random effects meta-analysis (19).

Grading system

Evidence was graded based on an analysis of outcome measures. The overall quality of evidence is presented using the GRADE approach recommended by the Cochrane Handbook for Systematic Reviews of Interventions (19). That is, for each specific outcome, five factors were scrutinized: (i) limitations of the study design or the potential for bias across all studies accordingly to the measure of a particular outcome, (ii) consistency of results, (iii) directness (generalizability), (iv) precision (sufficient data), and (v) the potential for publication bias. The overall quality was considered to be high if multiple RCTs with a low risk of bias provided consistent, generalizable results for the outcome. The quality of evidence was downgraded by one level if one of the factors described above was not met. Likewise, if two or three factors were not met, the level of evidence was downgraded by two or three levels, respectively. Thus, the GRADE approach resulted in four levels of quality of evidence: high, moderate, low, and very low. When a given outcome was measured by only one study, data were considered to be 'sparse', and subsequently, the evidence was labeled as 'low quality'. The systematic approach suggested by the GRADE working group was followed using the GRADE profiler software (version 3.2 for Windows. Jan Brozek, Andrew Oxman, Holger Schünemann, 2008) (20–24).

Quality of evidence classification is needed to ascertain whether an estimate of the effect is adequate to support a particular recommendation for the clinician. Strength of recommendation was performed according to the quality of the supporting evidence and classified as strong or weak for the use of functional textiles, through the balance of desirable/undesirable outcomes (20–24).

Results

Thirteen studies met the eligibility criteria and were included in our review. Fig. 1 shows the flow chart of the study selection strategy, and Table 1 shows the studies included. One study, an expert's bibliographic review, was excluded because did not met the inclusion criteria (25). Table 2 includes the classification of functional textiles according to their active compound.

The studies included participants aged between 4 months and 70 yr, with no restriction in disease severity. The interventions included silver (13, 14, 17, 26, 27), silk (28–33), borage oil (15), and EVOH fiber (16) used for a period of 1–12 wk. RCTs addressed silk textiles in two studies (28, 32), silver-coated textiles in 4 (13, 17, 26, 27), and borage oil (15) and EVOH fiber (16) in one study each. The case–control studies analyzed silk fabric (30, 31) and silver-coated textile (14). Silk textiles were also examined in one side-by-side comparison study (29) and one uncontrolled study (33). Silver-coated fabrics were studied in both children and adults in all cases (13, 14, 17, 26, 27). Silk, by contrast, was studied mostly in children (28–31), and borage oil (11) and EVOH fiber (12) were studied in children only. Control textiles included cotton (for studies of silver, borage oil, and EVOH fiber) and regular silk for studies of silk with AEGIS antibacterial treatment (28, 30–32). All the studies addressed eczema severity, measured by SCORAD (13–17, 26–28, 30, 32) and the Eczema Area and Severity Index (EASI) (29, 33). The skin microbiome was analyzed in studies of silver (14, 17, 26) and silk (31), while skin physiology was studied in those of silver and borage oil (15, 26, 27). Safety was assessed in studies of silver (13, 17, 26) and silk (29) textiles. Considering the reported outcomes, all the studies

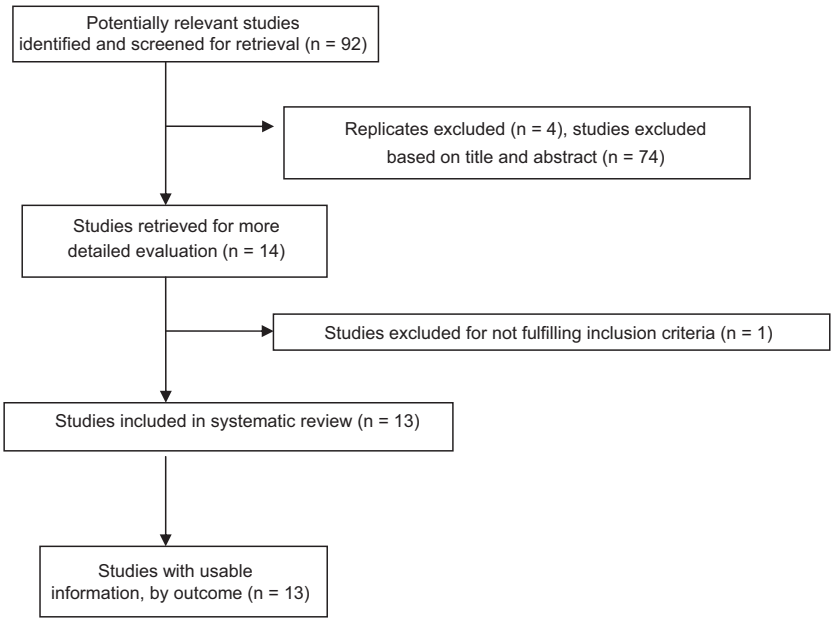

Figure 1 Flow-chart of included studies.

were deemed to have a low or very low quality of evidence (Table 3, Grade Evidence Profile and Table S1).

AD severity (SCORAD)

SCORing Atopic Dermatitis was used in 10 studies (13–17, 26–28, 30, 32), involving all kinds of interventions. Compared with placebo, a significant improvement in disease severity was observed for silver in two studies (13, 27) and for silk, also in two studies (28, 32). In the remaining studies, there was a reduction in disease severity, but no comparisons were made with placebo.

Meta-analysis was possible in two RCTs of silver-coated fabrics reporting a reduction in eczema severity (mean difference −12.66 [−21.26; −4.07], $I^2 > 60\%$) (13, 17) (Fig. 2).

AD severity (EASI)

Two studies analyzing silk used the EASI to evaluate AD severity. Senti et al., using a side-by-side comparison method, showed a significant decrease in severity, but they did not detect any differences between the side of the body in contact with the treated silk fabric and the other side (29). Kurtz et al. (33), in an uncontrolled study, reported a decrease in EASI following the use of a silklike-bedding fabric.

Symptoms

Five studies, using silver (13, 17), silk (28, 32), and borage oil (15), reported AD symptoms of pruritus and sleep loss as separate outcomes. In the silver group, no significant differences were found in the trial by Gauger et al. (13) for pruritus and sleep loss; Juenger et al. (17), by contrast, showed a significant reduction in symptoms in individuals who used silver textile, but they did not perform a comparison with placebo. In studies examining silk, a significant improvement in symptoms was seen in the active group; these studies were included in a meta-analysis due to their homogeneity (mean difference −1.74 [−2.19; −1.30], $I^2 = 0\%$) (28, 32) (Fig. 3). The trial of cotton undershirts coated with borage oil also reported a reduction in symptoms in the active group, but there was no comparison with placebo (15).

Quality of life

Quality of life in patients with AD was assessed using different tools. Gauger et al. (13), using the German Instrument for Assessment of Quality of Life in Skin Diseases (DIELH), showed an overall improvement in quality of life among patients who wore silver-coated garments, but they did not detect any significant differences with patients who wore untreated cotton garments. Kurtz et al. (33), using a study-specific quality of life index, assessed every 2 wk up to 8 wk, saw a progressive improvement in quality of life in patients who used silklike bedding, but there was no comparison with controls.

Rescue medication

The use of rescue medication (topical corticosteroids) was addressed only in studies evaluating silver textiles. Juenger et al. (17), using data from the first 2 wk of the trial, analyzed the use of prednicarbate ointment (measured in grams) as rescue medication in three groups (those who used silver textile, those who used silver-free textile, and those who used prednicarbate ointment regularly), and found that the quantity

Table 1 Studies included in the systematic review

References	Study design and subjects	Intervention	Outcome	Results
Gauger et al. (14)	Case–control; 15 subjects, aged 3–55 yr	Silver-coated tubular sleeves vs. cotton for 7 days, and 7 days follow-up	AD severity	Reduction in SCORAD score in silver-coated textile (no comparison with placebo)
			Microbiome	Significantly lower *Staphylococcus aureus* colonization
Ricci et al. (30)	Case–control; 46 children aged 4 months–10 yr	Silk undershirts, leggings, tubular sleeves on arms, and legs vs. cotton for 7 days	AD severity	Significant decrease in SCORAD index (reduction in mean local score ($p = 0.001$) in active group. No comparison with placebo
Juenger et al. (17)	RCT; 30 subjects, aged 4–70 yr	Undershirts and pants for 2 wk: silver vs. cotton vs. prednicarbate ointment, followed by silver textile in all groups	AD severity	Improvement in SCORAD index in the first 2 wk: from 74.60 to 29.95 in the silver group ($p = 0.005$) and from 57.80 to 24.00 in the steroid group ($p = 0.009$). No comparison with placebo
			Symptoms	Reduction in pruritus severity in the silver group ($p = 0.031$)
			Rescue medication	Similar to regular steroid group, more than in placebo group
			Microbiome	Significant reduction ($p = 0.003$).
			Safety	No adverse event
Gauger et al. (13)	Double-blind RCT; 57 subjects, median age 17.7 yr	Silver-coated tubular long-sleeves and long-legged pants for 2 wk	AD severity	Reduction in SCORAD index: 27.4% in silver group and 16.3% in placebo ($p < 0.001$)
			Symptoms	Improvement in pruritus and sleep, nonsignificant differences between groups
			Quality of life	Improvement in 18.9% from baseline compared with 17.1% in placebo; no significant differences between groups
			Rescue medication	16% less topical steroids in active group versus placebo
			Safety	No side effects
Senti et al. (29)	Side-by-side comparison study; 15 children, 1–5 yr	Silk vs. cotton with topical steroids	AD severity	No difference between groups
			Symptoms	No difference between groups
			Safety	One flare-up in active group
Ricci et al. (31)	Case–control, 16 children, aged 2–8 yr	Tubular sleeves made of silk vs. antimicrobial silk for 7 days	AD severity	Reduction in local SCORAD index in active and placebo groups ($p = 0.019$ and $p = 0.02$) No comparison between groups
			Microbiome	No significant reduction in *S. aureus* colonization in both groups
Khanehara et al. (15)	Double-blind RCT in 32 children, aged 1–10 yr	Undershirts coated with borage oil vs. cotton	AD severity	Reduction in erythema ($p = 0.033$)
			Symptoms	Reduction in pruritus ($p = 0.033$)
			Skin physiology	Significant decrease in TEWL ($p = 0.0480$), no differences with placebo group
Yokoyama et al. (16)	Double-blind RCT, 21 children aged 3–9 yr	EVOH fiber underwear for 4 wk	AD severity	Improvement in SCORAD index in active group only ($p = 0.001$). Objective SCORAD improvement in both groups No comparison between groups
Koller et al. (28)	RCT, 22 children, aged 5–12 yr	Tubular sleeves made of silk vs. antimicrobial silk for	AD severity	Reduced severity in active group in the first 2 wk ($p < 0.05$) but not

Table 1 (Continued)

References	Study design and subjects	Intervention	Outcome	Results
		2 wk, followed by cotton vs. antimicrobial silk for 10 wk		significant when compared to simple silk; significant differences at 4, 8 and 12 wk ($p < 0.001$)
			Symptoms	No difference in symptoms in the first 2 wk, significant differences at 4, 8, and 12 wk ($p < 0.001$)
Stinco et al. (32)	Double-blind RCT, 30 patients aged 3–31 yr	Tubular sleeves with silk coated with antimicrobial compound vs. silk	AD severity	SCORAD reduction significantly higher in active group (mean 10.05 ± 9.22, $p < 0.0001$)
			Symptoms	Decrease in pruritus in both groups, mean value of pruritus between groups favors active group
Kurtz et al. (33)	Uncontrolled study, 37 patients, aged <1 –69 yr	Silklike-bedding fabrics	AD severity	Significant decrease in AD area and severity index
			Symptoms	Significant decrease in itch score
			Quality of life	Increase in study-specific quality of life score
Fhur et al. (26)	Single-blind RCT; 37 subjects aged 12–60 yr	Silver-loaded T-shirts for 12 wk	Microbiome	Significant reduction in *S. aureus* colonization
			Skin physiology	Reduction in TEWL ($p = 0.0171$) in mildly involved skin in the silver group; nonsignificant improvement in severely involved areas
			Safety	No adverse events
Park et al. (27)	RCT single–blinded study; 14 subjects aged 6–35 yr	Silver vs. cotton T-shirts and leggings, side-by-side comparison for 4 wk	AD severity	Reduction in SCORAD index in active group
			Skin physiology	Reduction in TEWL ($p = 0.008$, 95% CI 1.1–6.71)

AD, atopic dermatitis; CI, confidence interval; EVOH, ethylene vinyl alcohol; RCT, randomized clinical trial; SCORAD, SCORing for atopic dermatitis; TEWL, transepidermal water loss.

Table 2 Classification of functional textiles according to active compounds

Functional textile	Textile composition	Type of fabric	References
Silver	Silver-loaded cellulose fabric with incorporated seaweed	Long-sleeved shirts and leggings	(26, 27)
	Silver-coated nylon fibers	Long-sleeved shirts and leggings	(17)
	Silver coated nylon fibers and polyamide	Long-arm undershirts and pants for adults, whole-body clothes for children	(13, 14)
Borage oil	Borage oil chemically bonded to cotton fibers	Undershirts	(15)
Ethylene vinyl alcohol fiber	Alternately arranged hydrophilic and hydrophobic nanoscale segments	Underwear	(16)
Silk	Sericin-free silk treated with AEGIS/AEM 5772/5	Tubular sleeves	(28, 31, 32)
		Whole-body romper suites, long-sleeved T shirts, panty hoses	(29)
	Microair Sericin-free silk treated with AEGIS/AEM 5772/5	Body suits, rompers, leggings, tubular bands, gloves, waist bands	(30)
	Silklike 50% polyester and 50% nylon	Bedsheets	(33)

of rescue medication used by patients in the silver group was similar to that used by the regular steroid group and higher than that used in the silver-free group. In the study by Gauger et al. (13), the percentage of patients who needed topical steroids was 16% lower in the group that wore silver-coated garments than in the group that wore cotton garments.

Table 3 Summary of findings. Functional textiles for atopic dermatitis

Patient or population: patients with atopic dermatitis; intervention: functional textiles					
	Illustrative comparative risks* (95% CI)				
Outcomes	Assumed risk	Corresponding risk	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
Severity – SCORAD SCORAD and adaptations[1] Scale: 0–103	The mean SCORAD score in the control groups was 30.4 points[2]	The mean SCORAD score in the intervention groups was 12.7 lower (4.07–21.26 lower)	77 (2)	⊕⊕⊖⊖ low[3]	Data presented are only from the studies included in the meta-analysis
Other severity scales [4] EASI Follow-up: mean 4 wk	Not estimable	Not estimable	67 (2)	⊕⊖⊖⊖ very low[3,5]	
Patient-rated symptoms Visual scale analogic (0–10) Scale: 0–10	The mean patient-rated symptom score in the control groups was 5.55 points	The mean patient-rated symptom score in the intervention groups was 1.74 lower (2.19–1.3 lower)	104 (2[6])	⊕⊕⊖⊖ low[3,5,6]	Data presented are only from the studies included in the meta-analysis
Quality of life Quality of life questionnaire Scale from 0 to 110 Follow-up: mean 8 wk	Not estimable	Not estimable	94 (2[5,7])	⊕⊖⊖⊖ very low [5, 7,	
Need for rescue treatment Weight (in grams) of moderately potent corticosteroid cream used Scale: 0–200 Follow-up: 2 wk	Not estimable	Not estimable	87 (2[8])	⊕⊕⊖⊖ low[3,5,8]	
Skin microbiome Reduction in number of colony-forming units of *Staphylococcus aureus* Scale: 0–10 Follow-up: 8 wk[9]	Not estimable	Not estimable	122 (4)	⊕⊖⊖⊖ very low[3,5]	
Skin physiology Transepidermal water loss. Scale from 0 to 15 Follow-up: 8 wk	Not estimable	Not estimable	93 (3[10])	⊕⊕⊖⊖ low[3,11]	

Table 3 (Continued)

Patient or population: patients with atopic dermatitis; intervention: functional textiles					
	Illustrative comparative risks* (95% CI)				
Outcomes	Assumed risk	Corresponding risk	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
Safety Urine and serum silver levels Follow-up: 8 wk	Not estimable	Not estimable	65 (2[12])	⊕⊖⊖⊖ very low[3,13]	
Dropout due to eczema flare-up Timing of exposure: 2 wk	Not estimable	Not estimable	15 (1)	⊕⊖⊖⊖ very low[14]	

*The basis for the assumed risk (e.g., the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; OR: odds ratio; SCORAD, SCORing Atopic Dermatitis (SCORAD) index.

GRADE Working Group grades of evidence.

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

[1]SCORAD was evaluated using four variations: mean total SCORAD score (13, 17, 30), objective SCORAD index (30, 32), local SCORAD index (14, 28, 31), and modified local SCORAD index (15, 27).

[2]Final SCORAD score.

[3]Small sample.

[4]Evaluated in studies with a different methodology: Senti et al. (29) (side-by-side comparison study) and Kurtz et al. (33) (uncontrolled study).

[5]Lack of allocation concealment.

[6]Patients also served as controls in both studies.

[7]Different study designs linked together: Gauger et al. (13) (randomized controlled trial) and Kurtz et al. (33) (silklike-bedding, no control group).

[8]Data reported only by Juenger et al. (17). The use of rescue medication was compared between three groups in the first 2 wk of the trial (135 g of corticosteroid ointment per participant in the silver-textile group, 13 g in the silver-free textile group, and 145 g in the topical corticosteroid group. Gauger et al. (13) only reported the percentage of patients using topical steroids as rescue medication (84.4% in placebo group versus 68.6% in the silver group).

[9]All interventions lasted 1–2 wk except in the Fluhr et al. (26) study, in which they lasted 8 wk.

[10]Two randomized controlled trials (26, 27) assessing silver textile and one assessing borage oil (15). Park et al.(27) performed a side-by-side comparison study.

[11]The silver textile trials (26, 27) were single-blinded.

[12]One randomized control trial (26) tested serum silver measurements and a phase II randomized trial (17) measured urinary silver levels (only the first 2 wk of the intervention were considered).

[13]Single-blinded study, randomization methods not described. Outcome divided according to mild and severe atopic dermatitis, not detailed in methods (26).

[14]Side-by-side intervention study.

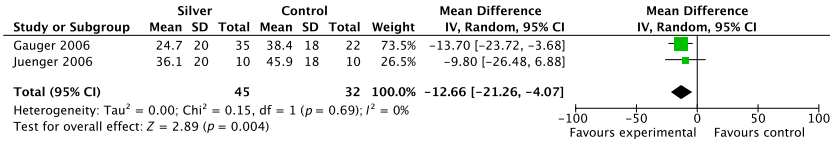

Figure 2 Metanalysis of SCORAD results (silver functional textiles versus placebo).

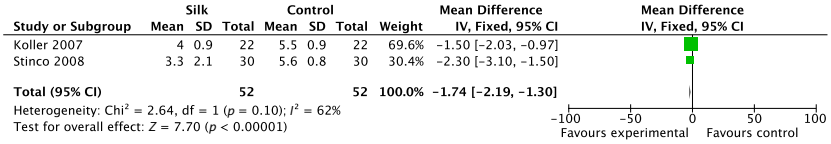

Figure 3 Metanalysis of atopic dermatitis symptons results (silk functional textiles versus placebo).

Skin microbiome

The effect of interventions on the skin microbiome was evaluated in terms of *S. aureus* colonization (mean number of colony-forming units [CFUs] per cm^2). Of the three studies analyzing silver textiles (14, 17, 26), the two RCTs (17, 26) showed a significant reduction in *S. aureus* colonization. In a case–control study of a silk fabric coated with AEGIS, a non-significant reduction in CFUs was seen in both cases and controls (31).

Skin physiology

Skin physiology was assessed by transepidermal water loss (TEWL) in three studies: two involving silver (26, 27) and one involving borage oil (15). In a side-by-side comparison study, compared with placebo, a significant decrease in TEWL was detected after 4 wk in patients who wore a silver-loaded fiber (26). In the other study of silver, similar results were obtained for mildly involved skin, but not for skin with more severe disease (27). In the borage oil study, TEWL decreased in the study and control groups, but the differences were not significant (15).

Safety

The systemic absorption of silver through the skin in patients who wore fabric impregnated with silver was evaluated by urine and serum silver measurements in two studies (17, 26), with no persistent increases detected. In a study of an antimicrobial silk fabric by Senti et al. (29), one of the patients dropped out at day 4 due to a flare in both treated and untreated skin areas.

Discussion

This systematic review found that the use of functional textiles in atopic dermatitis is safe and associated with a slight improvement in disease severity, symptoms, and quality of life. However, any recommendations for the use of these textiles as part of standard AD management are hampered by the low quality of supporting evidence. Different textile components are associated with different effects. Silver-coated cotton, for example, seems to be more effective in decreasing lesion severity, while silk fabrics appear to be more likely to alleviate pruritus and symptoms.

The evidence for the effectiveness of functional textiles in AD was qualified using the GRADE approach. In addition to an overall lack of evidence supporting the use of functional textiles in AD, the quality of evidence in the studies included in our review was either low or very low, mainly because they were non-randomized, non-controlled studies, which furthermore were underpowered to detect treatment effects due to small sample sizes. Short follow-up might also have reduced the ability to see true effects, possibly explaining why some studies did not detect differences between placebo and intervention groups. The use of different textiles, with different active compounds and therefore different physical and antimicrobial properties, prevented direct comparisons between studies. Accordingly, we only performed a meta-analysis of studies that evaluated the same interventions and outcomes. The limitations of this review are explained by the limitations of the studies included.

Atopic dermatitis is a complex disease that requires a multidimensional treatment approach (34). Control of environmental factors (35) and dietary intervention (36) have been proposed as the ultimate focus on atopic dermatitis management endorsing tolerance, prevention, and promotion of health attitudes instead of prompt medical treatment (37). Non-pharmacological strategies, as functional textiles, have been studied and represent an interesting therapeutic option for patients with AD (34, 38).

All the studies analyzed in this review that addressed eczema severity reported some benefits from using functional textiles, but the majority did not compare results with those from a control group. Due to differences in study design, interventions, and outcome measures, we were only able to pool data on SCORAD in two studies (13, 17), both of which analyzed silver-coated textiles. The meta-analysis showed a trend in favor of the use of these textiles.

Silver seems to exert its effect on eczema severity through its antimicrobial properties (39), diminishing colonization by *S. aureus* and consequently attenuating inflammation and consequent exacerbation of lesions. Nevertheless, definitive conclusions cannot be drawn, as we analyzed only two studies, with different designs and small sample sizes.

Silk textiles may affect overall disease status by improving comfort and reducing itch sensation. Almost all the studies of silk analyzed in this review used specific types of silk fabrics made of transpiring and slightly elastic woven silk, free of sericin (a protein assumed to be irritant to the skin), and impregnated with AEGIS, an antibacterial compound (28–32). The exception was the study by Kurtz et al. (33), which did not state which antimicrobial was used. Silk did not have a significant effect on *S. aureus* colonization, although this was analyzed in just one study (29). The use of silver textile, however, was significantly associated with a reduction in *S. aureus* colonization; the difference in effects may possibly be due to different mechanisms of action. (39) The use of EVOH fiber in AD is intended to reduce pruritus, as fabrics treated with EVOH have a smooth texture. However, in our review, the single study that analyzed EVOH fiber reported an improvement only in erythema. Borage oil has been previously used in AD to restore skin barrier lipids as an oral supplement, with conflicting results (40, 41). The lack of comparison with placebo in the study analyzing borage oil–coated textiles in our review (15) made it impossible to draw any definitive conclusions on effectiveness.

Functional textiles used in AD are designed not only to reduce disease severity, but also to alleviate symptoms. In most cases, the aim is to improve pruritus and sleep loss, two of the most distressing features of AD. Most of the studies we reviewed reported improvements in pruritus and sleep disturbance following the use of specially treated fabrics, but in half of the studies, no between-group comparisons were made. The use of silver-impregnated cotton fabric with an antimicrobial effect may contribute to the relief of symptoms. The two studies that analyzed silk reported a significant decrease in symptoms, and the meta-analysis of pooled data suggested that this fabric might be effective in improving the symptoms of AD. However, due to the small number of studies and small sample sizes, a definitive conclusion cannot be drawn.

A reduction in symptoms and colonization by *S. aureus* may also have an impact on quality of life. Nevertheless, the different tools used to measure this outcome—and the different study designs—prevent any conclusions from being made. The need for rescue medication was addressed in two studies (13, 17), but the results are not comparable as different outcomes were used (quantity of medication used and percentage of participants requiring medication).

The impact of the use of functional textiles on the skin microbiome was evaluated in only four studies (14, 17, 26, 31), even though a reduction in skin colonization by *S. aureus* is one of the aims in the use of functional textiles. Beneficial results were seen only with silver, which is understandable given its antimicrobial properties, but no conclusions can be drawn due to the low quality of the supporting evidence. Measures of skin physiology are also important when evaluating skin inflammation. Improvements in TEWL may result from a reduction in skin inflammation associated with a reduction in pruritus and bacterial colonization favored by the use of functional textiles. In our review, we detected conflicting results in the study by Park et al. (27), which showed less or no TEWL improvement in patients with more severe forms of AD.

Although the studies included in this review analyzed different populations, age groups, and degrees of disease severity, only one adverse event—an eczema flare-up—was reported. The event, however, could not be directly linked to the intervention (use of antimicrobial silk fiber), because both treated and untreated areas were affected (29).

The methodological quality of future studies of functional textiles in AD needs be improved to enable similar outcomes to be analyzed across different textiles. The emergence of new compounds may also offer improved effectiveness (42). An appropriate sample size should be calculated according to the evaluated outcomes and type of study design. The possibility of targeting specific AD phenotypes (43) (e.g., *S. aureus* colonization, atopic versus non-atopic, presence or absence of filaggrin gene mutations) may also improve the performance of certain textiles in subgroups of patients. The role of functional textiles in AD needs to be addressed by more studies, with longer follow-up and an improved design.

Conclusions

Based on the low quality of evidence supporting the effectiveness of functional textiles in alleviating symptoms and reducing disease severity in AD, the strength of the recommendation to use these textiles in this setting is weak.

Different textile components are associated with distinct effects; silver-coated fabrics, for example, seem to be more effective at diminishing the severity of lesions, while silk fabrics seem to perform better in terms of alleviating pruritus and other symptoms. Considering the high prevalence of AD, more studies are needed to confirm these data, identify which mechanisms are targeted, and determine how functional textiles contribute to symptom improvement. RCTs with larger sample sizes, longer follow-up periods, new bioactive compounds, and comparisons of similar time interventions and homogeneous study groups in terms of AD severity are needed. The results of such studies could help to identify patients who might benefit most from the use of functional textiles and to determine which textiles are most appropriate in given situations.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Grade evidence profile table, assessing the question: should functional textiles be used for atopic dermatitis?