REVIEW ARTICLE

Prevention of Friction Blisters in Outdoor Pursuits: A Systematic Review

Robert M. Worthing, MD; Raechel L. Percy, DO; Jeremy D. Joslin, MD

From the Physical Medicine and Rehabilitation Service, Veterans Affairs Medical Center, Lexington, KY (Dr Worthing); the Department of Physical Medicine and Rehabilitation, University of Kentucky, Lexington, KY (Dr Percy); and the Department of Emergency Medicine, State University of New York Upstate Medical University, Syracuse, NY (Dr Joslin).

The purpose of this systematic review was to determine if sock, antiperspirant, or barrier strategies were effective in prevention of friction blisters in wilderness and outdoor pursuits. A search of PubMed and EMBASE was conducted. Title, abstract, and full text articles were screened by 2 authors using predetermined inclusion and exclusion criteria to identify prospective controlled trials investigating prevention methods for friction blisters involving the foot. Only blisters associated with wilderness and outdoor pursuits (running, hiking, marching, etc.) were considered. Extraction of a predetermined data set was accomplished using a piloted form. Confidence in effect estimates were determined utilizing the Scottish Intercollegiate Guidelines Network methodology checklist. Literature search resulted in 806 discrete articles. After screening, 11 studies were identified for inclusion in systematic review. Included studies investigated 5 sock, 3 antiperspirant, and 3 barrier strategies. Only 2 articles were determined to have moderate confidence in effect estimate. Clinical and methodologic diversity precluded meta-analysis. Despite the high frequency, discomfort, and associated cost there is a paucity of high-quality quality evidence in support of socks, antiperspirants, or barriers for the prevention of friction blisters. Moderate confidence in effect estimate suggests that paper tape may be an effective form of barrier prevention.

Keywords: blister, friction, foot, running

Introduction

Friction blisters involving the foot represent a common injury in active individuals engaged in wilderness and outdoor related pursuits. Among long distance hikers and backpackers, reported blister rates range from 54 to 86%.^{1,2} Studies involving military personnel report blister rates ranging from 5 to 77%.^{3,4} Studies involving ultramarathon and adventure racing report blister rates ranging from 26 to 76%.^{5,6} In fact, foot blisters have been cited as the most common medical complaint among hikers⁷ and ultramarathon/adventure racers alike.^{8–10} Although often regarded as a minor injury, the impact of friction blisters is not inconsequential. In competitive single-stage ultramarathons, Hoffman and Fogard reported 40.1% of finishers cited friction blisters as adversely affecting race

performance.⁵ A study of US Marine Corps recruits participating in initial training evolutions at Marine Corps Recruit Depot San Diego, CA, attributed an estimated annual expense of \$690,000 to friction blisters.⁴

Friction blisters result from pressure and shear forces causing delamination at the level of the stratum spinosum.¹¹ Risk factors include but are not limited to moisture, temperature, external load, activity duration, characteristics of footwear, and adaptation/conditioning.^{11–15} Each of these risk factors influence frictional force (F_f), where $F_f = \mu \times F_n$. Prevention and treatment strategies therefore seek to reduce the coefficient of friction (μ), pressure or shear force (F_n), frequency of force application, or any combination thereof. Such strategies include any combination of sock fibers, sock piles, sock layers, barriers such as tapes and plasters, antiperspirants, lubricants, and orthotics. Despite a multitude of published studies on the subject, friction blisters remain a common and debilitating injury among participants in wilderness and outdoor pursuits, and there remains no widespread consensus on effective prevention strategies.^{14,16–18}

Corresponding Author: Robert M. Worthing, MD, Physical Medicine & Rehabilitation Service, Veterans Affairs Medical Center, 1101 Veterans' Drive, Lexington KY 40502-2236; e-mail: Robert.worthing@va.gov

Submitted for publication July 2016.

Accepted for publication March 2017.

We conducted a systematic search and qualitative analysis of prospective controlled trials to determine if sock, antiperspirant, or barrier strategies were effective in prevention of friction blisters of the foot in wilderness and outdoor pursuits.

Methods

Study design and methodology was predetermined through collaboration of all authors following guidelines in the PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses.¹⁹ Methods of analysis and criteria were documented in a written protocol in advance of the study.

SEARCH STRATEGY

Two electronic databases (PubMed, EMBASE) were systematically searched to identify prospective controlled trials investigating prevention strategies for friction blisters of the foot. The search strategy was formulated in collaboration with appointed university librarians from multiple institutions using a peer review process. No restriction on date or language of publication was applied. Details of this search strategy including discrete search terms utilized may be found in [Appendix 1](#) (e-component). Database searches were conducted on May 20, 2016, and duplicates removed using EndNote citation manager software (Thomson Reuters, New York, NY). A secondary search of those references included in identified publications, and a tertiary search involving expert consultation, was subsequently conducted.

STUDY SELECTION

Two reviewers independently conducted title, abstract, and manuscript review using predetermined inclusion and exclusion criteria. Inclusion criteria consisted of the following: publications were original, prospective controlled trials (randomized controlled trial, prospective controlled cohort, case crossover, etc.); subjects were recreational or professional, military or civilian, engaged in wilderness and outdoor related activity (military evolutions, hiking, running, etc.); the intervention was for prevention of friction blisters (sock systems, liquid and powder antiperspirants, tapes, etc.); and outcome measures included incident data. All settings (desert, tropical, laboratory, etc.) were accepted. Exclusion criteria consisted of the following: case reports, case series, cross-sectional or descriptive studies; publications limited to abstract only; field- and water-based sports (soccer, basketball, rowing, etc.); blisters not of the foot; blisters created by artificial means or secondary to

identifiable pathology (diabetes, vascular stasis, dermatologic conditions, etc.); and cases involving complication (infection, ulceration, chronic wounds, etc.). Reviewers remained blinded to results during review. A third reviewer subsequently mediated any dispute.

DATA COLLECTION

To assess diversity, a summary description of included full text articles was prepared utilizing a piloted form. Extracted data included the following: primary author and year of publication; study design; population (including mean age where provided); setting (including distance/time where provided); number of subjects; description of the intervention; outcome measures; and reported results (including incident data). In preparation for quality assessment, study design was determined using the Scottish Intercollegiate Guidelines Network Study Design Algorithm.²⁰ Studies were organized alphabetically within 3 groups based on intervention (socks, antiperspirants, or barriers).

Assessment of risk of bias and confidence in effect

Assessment of risk of bias and confidence in effect estimate was performed in the context of blister risk ratio with reference to the Cochrane Handbook for Systematic Reviews of Interventions²¹ and utilizing the Scottish Intercollegiate Guidelines Network Methodology Checklist 2: Controlled Trials.²⁰ The checklist includes 10 elements for assessment of internal validity, including identification of a clearly focused question, method of randomization and concealment, blinding, similarity of treatment and control groups, outcome measure, dropout rate, intention to treat analysis, and comparability of results across sites where applicable. Minimization of bias in study design was coded as high, acceptable, or unacceptable (low) based on rater interpretation of relative risk, direction, and magnitude of bias effect. Only those studies determined to be of high or acceptable bias control were assessed for confidence in effect estimate. Risk ratio, confidence interval, and statistical significance for individual studies were calculated using MedCalc (MedCalc Software, Ostend, Belgium). A confidence in effect estimate was then determined through consideration of risk of bias, directness of evidence, consistency and precision of results, publication bias, and other identifiable methodological limitations. Confidence in effect estimates were coded as high, moderate, low, or very low in accordance with Grading of Recommendations Assessment, Development and Evaluation methodology.²² Two reviewers who remained blinded

to results independently assessed all studies. A third reviewer subsequently mediated any disagreements.

Results

A total of 806 titles in 12 languages were identified for screening. Dates of publication ranged from 1950 to 2016. Title and abstract review resulted in elimination of 786 studies. An additional 9 of the 20 remaining studies were excluded on manuscript review based upon previously outlined criteria. A total of 11 studies underwent data extraction and analysis (Figure).

Results of data extraction are summarized in Table 1.^{23–31} Studies included 5 controlled clinical trials and 6 randomized controlled trials with varying degrees of blinding. A total of 1838 subjects were represented. Populations were largely military from the United States, Europe, and China. Long distance recreational runners and endurance athletes were also represented.

A variety of interventions for blister prevention were investigated. Five studies investigated socks with different fiber content, sock knits, and combinations of sock systems (layered socks) with and without powdered

antiperspirants. Four antiperspirant formulations were investigated in 3 trials, 2 of which included placebo comparison. Three studies evaluated the prophylactic effect of barriers including paper tape and a proprietary plaster. Both subjective and objective measures were used across studies. Subjective outcome measures included perceived padding, comfort, dampness, temperature, subject preference, and satisfaction. In addition to blister incidence, objective outcome measures included blister severity, sweat accumulation, other foot injuries, musculoskeletal overuse injuries, skin irritation, and number of “sick visits.”

Results of risk of bias and confidence in effect estimate assessments are summarized in Tables 2^{3,18,23–31} and 3,^{18,25–27,29–31} respectively. Identified prospective controlled trials included both positive and negative results, suggesting publication bias is unlikely. Of the 11 studies evaluated, 4 were noted to be of low bias control and excluded from further assessment. Of the 7 remaining studies, 4 were determined to be of acceptable bias control and 3 of high bias control. Calculated risk ratios met statistical significance ($P < .05$) for 2 sock and 2 barrier studies. No antiperspirant studies met

Figure. Flowchart outlining study selection for systematic review.

Table 1. Summary description of studies

<i>Intervention group</i>	<i>Reference</i>	<i>Design</i>	<i>Population</i>	<i>Setting</i>	<i>Subjects</i>	<i>Intervention(s)</i>	<i>Outcome measure(s)</i>	<i>Results</i>
Sock systems	Herring & Richie ²³	Double-blind controlled clinical trial	Recreational long distance runners, age male 34.4±10.4 (mean±SD), female 29.1±9.6	Series of 45–180 minute runs over 10–30 days	35	Acrylic sock plush knit vs cotton sock plush knit	<ul style="list-style-type: none"> – Blister incidence – Skin injury size (mm²) – Blister anatomic location – Blister severity (scaling system) – Padding (Yes/No) – Shoe–Sock adhesions (Yes/No) – dampness & temperature (scaling system) 	<ul style="list-style-type: none"> – Acrylic with lower blister incidence (21 vs 33%; $P = .01$) – Acrylic with lower blister size (11% vs 34%; $P = .01$) – Acrylic with drier foot ($P = .02$) and drier sock ($P < .001$) – No significant difference in foot temperature, padding, or adhesions
	Herring & Richie ²⁴	Double-blind controlled clinical trial	Recreational long distance runners, age 38.1±9.4 (mean±SD)	Series of 45–180 minute runs over 10–30 days	27	Acrylic sock generic knit vs cotton sock generic knit	<ul style="list-style-type: none"> – Blister incidence – Skin injury size (mm²) – Blister anatomic location – Blister severity (scaling system) – Padding (Yes/No) – Shoe–Sock adhesions (Yes/No) – dampness & temperature (scaling system) 	<ul style="list-style-type: none"> – No significant difference in any outcome measure

Jagoda et al ²⁵	Nonblinded randomized controlled trial	Male US Marine Corps officers in training, age unknown	6 mi (9.6 km) military training march	221	I. Standard issue sock vs II. Desenex powder + nylon dress sock + athletic sock outer vs III. Desenex powder + athletic sock inner + green sock outer	<ul style="list-style-type: none"> – Blister incidence – Blister severity (No. × size in mm) 	<ul style="list-style-type: none"> – III. With lower blister incidence (21.6% vs 40.66% in II. and 58.86% in I.; <i>P</i> not calculated) – No significant difference in blister severity (<i>P</i> = .068)
Knapik et al ³	Nonblinded controlled clinical trial	Male US Marine Corps recruits, age unknown	12-week basic military training	357	I. SS (standard issue sock multifiber blend) vs II. SL (polyester inner + standard issue sock) vs II. PL (polyester inner + 50% wool/50% polypropylene thick nap outer)	<ul style="list-style-type: none"> – Blister incidence – No. sick-call visits 	<ul style="list-style-type: none"> – III. With lower blister incidence (40% vs 69% and 77%; <i>P</i> < .001 for both) – I. With more sick-call visits (RR = 2.5; <i>P</i> < .01)
Van Tiggelen et al ²⁶	Nonblinded randomized controlled trial	Belgian Royal Military Academy officer cadets, age unknown	6-week basic military training	173	I. 88% polyester padded sock vs II. 45% polyester thin inner + cotton/wool blend padded outer vs III. standard issue sock (70% wool)	<ul style="list-style-type: none"> – Blister incidence – Overuse injury (PFPS, ITB syndrome, patellar tendinopathy) 	<ul style="list-style-type: none"> – I. With lower blister incidence (15% vs 30% and 48%; <i>P</i> = .007 and < .001, respectively) – Overuse injuries associated with blisters (<i>P</i> < .001)
Antiperspirants Darrigrand et al ²⁷	Single-blind controlled clinical trial	Male US Army soldiers, age 23.2 ± 3.7 (mean ± SD)	1 hr treadmill march at 5.6 km/h in warm environment	19	ACH (23.5% aluminum chlorohydrate aqueous sole) vs AZG (23.5% aluminum zirconium tetrachlorohydrate glycine) vs control (no treatment)	<ul style="list-style-type: none"> – Foot injury incidence (blister, hot spots, irritant dermatitis, tinea pedis, plantar fasciitis) – Sweat accumulation (boot and sock mass) 	<ul style="list-style-type: none"> – No significant difference in blister incidence – Antiperspirants with > 50% reduction in sweat accumulation (<i>P</i> < .05) – Antiperspirants with 38% increase in irritant dermatitis (<i>P</i> < .05)

Table 1 (continued)

<i>Intervention group</i>	<i>Reference</i>	<i>Design</i>	<i>Population</i>	<i>Setting</i>	<i>Subjects</i>	<i>Intervention(s)</i>	<i>Outcome measure(s)</i>	<i>Results</i>
								– No significant difference in other foot injury incidence
	Knapik et al ²⁸	Double-blind controlled clinical trial	US Military Academy cadets, age unknown	13 mi (21 km) military training march	667	Antiperspirant (20% aluminum chloride hexahydrate in alcohol base) vs placebo (denatured alcohol base)	– Blister incidence – Skin irritation	– Antiperspirant with lower blister incidence (21 vs 48%; $P < .01$) – Antiperspirants with higher skin irritation incidence ($P = < .01$)
	Reynolds et al ²⁹	Double-blind randomized controlled trial	Male US Army soldiers, age 22 ± 2.9 (mean $\pm$ SD)	200 min treadmill march at 1.39 m/sec in warm environment	23	I. Antiperspirant (20% aluminum zirconium tetrachlorohydrate glycine + emollient) vs II. placebo (emollient alone) vs III. no treatment	– Sweat accumulation (boot and sock mass) – Dermal injury incidence (hot spot, blister, irritant dermatitis) – Blister size (mm) – Pain (AS)	– No significant difference in any outcome measure reported – No cases of irritant dermatitis reported
Barriers	Lipman et al ³⁰	Nonblinded randomized controlled trial	Endurance athletes, age 39.7 ± 9.4 (mean $\pm$ SD)	155 mi (250 km) 7-day adventure ultramarathons	90	Prophylactic paper tape application vs no treatment	– Blister incidence – Subject exit survey	– No significant difference in blister incidence – 84% of participants would use prophylactic tape again

Lipman et al ¹⁸	Nonblinded controlled trial	Endurance athletes, age 39.3±8.3 (mean ± SD)	155 mi (250 km) 7-day adventure ultramarathons	128	Prophylactic paper tape application vs no treatment	<ul style="list-style-type: none"> – Blister incidence – Subject exit survey 	<ul style="list-style-type: none"> – Paper tape with absolute reduction of blister incidence of 40% ($P < .01$) – 81% of participants would use prophylactic tape again
Tan et al ³¹	Nonblinded randomized controlled trial	Male Chinese Army recruits, age 18–19	10 mi (16 km) military march in tropical environment	98	Blist-o-Ban (proprietary plaster) vs no treatment	<ul style="list-style-type: none"> – Blister incidence 	<ul style="list-style-type: none"> – No blisters formed under plaster vs 46 blisters in areas not protected by plaster

RR, relative risk; PFPS, patellofemoral pain syndrome; ITB, iliotibial band.

statistical significance. Confidence in effect estimate was determined to be moderate for 2 studies involving a paper tape barrier method. In the Prevention Trial Assessing Paper-Tape in Endurance Distances,³⁰ the authors reported no significant difference in blister incidence between prerace application of paper tape compared with the untreated contralateral foot (calculated relative risk 1.23; 95% CI 0.97–1.68; $P = .08$). On the experimental foot, fewer blisters were noted around the tape compared with under the tape. A substantial number of participants (44%) did not complete the study. In the Prevention Trial Assessing Paper-Tape in Endurance Distances II,¹⁸ the same authors modified the comparator such that uncovered areas of the experimental foot served as the control. This second study was incompletely randomized, with the experimental area chosen by convenience in those racers that reported prior blisters (92%), and at random in those racers who did not report prior blisters. The authors reported a 40% absolute reduction in blister formation (calculated relative risk 0.49; 95% CI 0.37–0.66; $P < .01$). The primary author reports a potential conflict of interest involving the promotion of the barrier method of study in 2 for-profit wilderness publications. Confidence in effect estimate was low or very low for the remainder of the studies. A detailed narrative of assessments for each study may be found in [Appendix 2](#) (e-component).

[Table 4](#) summarizes clinical and methodological diversity identified among grouped studies. Diversity in study design, intervention, and comparator were common. Diversity was substantial and precluded meaningful multivariate meta-analysis with a priori grouping.

Discussion

The existing body of literature addressing friction blisters includes a number of narrative reviews. Most notable among these narratives is that published by Knapik et al in 1995, who included a detailed evidence-based review of pathophysiology, factors influencing blister formation, and recovery.¹¹ Additionally, there was at least 1 attempt at the formation of evidence-based clinical practice guidelines for the prevention and treatment of friction blisters,¹⁶ where the subject was addressed in the greater context of wound management in austere environments. This approach limited the review methodology, accuracy of results, and applicability of resultant guidelines.¹⁷ The present systematic review followed standardized methodology consistent with Appraisal of Guidelines for Research and Evaluation in Europe II and Grading of Recommendations Assessment, Development and Evaluation. To our knowledge, this is the first

Table 2. Risk of bias assessment

Study	SIGN assessment criteria for risk of bias										Risk control
	1	2	3	4	5	6	7	8	9	10	
Herring & Richie ²³	Y	NA	NA	NA	Y	Y	Y	41%	N	Y	–
Herring & Richie ²⁴	Y	NA	NA	NA	Y	Y	Y	46%	N	Y	–
Jagoda et al ²⁵	Y	Y	N	N	Y	Y	Y	3%	UNK	NA	+
Knapik et al ³	Y	NA	NA	NA	UNK	N	Y	0%	Y	Y	–
Van Tiggelen et al ²⁶	Y	Y	N	N	UNK	Y	Y	8%	N	Y	++
Darrigrand et al ²⁷	Y	NA	NA	NA	Y	Y	Y	15%	UNK	Y	+
Knapik et al ²⁸	Y	NA	NA	NA	UNK	Y	Y	41%	N	Y	–
Reynolds et al ²⁹	Y	Y	N	Y	Y	Y	Y	UNK	UNK	Y	++
Lipman et al ³⁰	Y	Y	N	N	Y	Y	Y	44%	N	Y	+
Lipman et al ¹⁸	Y	N	N	N	Y	Y	Y	15%	Y	Y	++
Tan et al ³¹	Y	Y	N	Y	Y	Y	Y	2%	N	Y	+

Y, potential source of bias was addressed; NA, not applicable; N, source of bias that was not addressed; –, low quality of risk control (high risk of bias); UNK, inadequate information available to determine whether potential source of bias was addressed; +, acceptable risk; ++, high quality risk control (low risk of bias).

Categories assessed are as follows: 1) focused question; 2) randomization; 3) allocation concealment; 4) blinding; 5) similarity of control and treatment groups; 6) difference in treatment among experimental group(s); 7) outcome measure; 8) dropout rate; 9) intention to treat analysis; 10) compatibility across sites.

systematic review using evidence-based methodology dedicated to friction blister prevention to date.

Our analysis provides moderate confidence that the calculated risk ratio for paper tape versus no treatment is close to the true effect. This suggests that paper tape may be effective in preventing friction blisters among participants in wilderness and outdoor pursuits. There is low confidence in effect estimate for prospective controlled trials evaluating sock, antiperspirant, and alternative barrier strategies for friction blisters of the foot. Methodological flaws created potential for bias in all studies evaluated. Studies of lower quality bias control frequently experienced lack of blinding and randomization, high rates of dropout and noncompliance, and lack of intention to treat analysis. Studies with low confidence in effect estimate additionally experienced inclusion of co-interventions and imprecision of effect estimate. Studies determined to be of moderate confidence in effect estimate experienced similar methodological flaws, but when direction and magnitude of bias were considered in the context of the statistical power of the study, the overall effect remained likely due to the study intervention. We note a trend toward improved quality with more recent publication dates, correlating with the evolution of guidelines on conduction and reporting of controlled trials such as CONSORT.³² This is reflected in the relative quality of methodology and/or reporting displayed in the manuscripts of Van Tiggelen et al²⁶ and Lipman.^{18,30}

Limitations exist to the present review. Although criteria and methods of analysis were documented in a written protocol, our study design was not formally registered before implementation. The study was completed in a timely manner relative to search date, and automated monthly searches were utilized where available to ensure additional relevant publications did not appear during its execution. However, data from unpublished or ongoing studies was not considered, nor were findings in retrospective, case report, case cohort, or alternative designs. Inadequate reporting complicated risk of bias assessment in multiple studies. Finally, substantial clinical and methodological diversity prevented quantitative analysis despite use of P – patient, problem or population, I – intervention, C – comparison, control or comparator, O – outcome question format. It is critical to recognize this review is limited to determining the confidence in effect estimate within each study, and does not comment on the cumulative body of evidence for or against friction blister prevention strategies. Current clinical practice guidelines may not reflect the confidence in effect estimates outlined in this systematic review.

It is our opinion that, despite nearly 80 years of research, the existing body of literature does not yet provide sufficient evidence to support the formulation of robust, meaningful clinical practice guidelines. It is our intent that the present systematic review serve as a “call-to-arms” for the performance of additional clinical trials

Table 3. Assessment of confidence in effect estimate for individual studies

Study	Bias control	Other limitations	Effect estimate (RR with 95% CI)	Significance level (P)	Confidence in effect estimate	Comments
Jagoda et al ²⁵	+	Co-intervention	II. 0.69 (0.49–0.97) III. 0.37 (0.22–0.59)	II. .03 III. <.01	Low	
Van Tiggelen et al ²⁶	++	Multiple interventions	I. 0.38 (0.24–0.59) II. 0.71 (0.54–0.95)	I. <.01 II. .02	Low	
Darrigrand et al ²⁷	+	Imprecision	II. 0.11 (0.01–1.86) III. 0.75 (0.23–2.45)	II. .13 III. .63	Very low	– High rate of irritant dermatitis associated with treatment
Reynolds et al ²⁹	++	Imprecision	0.95 (0.51–1.75)	.86	Low	– No irritant dermatitis with emollient added
Lipman et al ³⁰	+	None	1.23 (0.97–1.68)	.08	Moderate	– Required reapplication – Well tolerated
Lipman et al ¹⁸	++	Potential COI	0.49 (0.37–0.66)	<.01	Moderate	– Required reapplication – Well tolerated
Tan et al ³¹	+	Co-intervention; potential COI	0.02 (0.0–0.30)	<.01	Low	

RR, risk ratio; COI, conflict of interest.

Very low indicates true effect is likely to be substantially different from the estimate, *Low* indicates true effect may be substantially different from the estimate, *Moderate* indicates the true effect is likely to be close to the estimate of effect, but the possibility of substantial difference remains.

evaluating prevention strategies for friction blisters of the foot using high quality, up-to-date methodology and reporting compliant with relevant guidelines such as CONSORT. Further studies evaluating sock systems should seek to eliminate co-interventions such as antiperspirants and evaluate single variables (fiber content, pile, layering, etc.). Any further study of antiperspirants should consider the potential for adverse effect and involve larger cohorts. Independent validation of prior

results through a randomized controlled trial evaluating paper tape versus no treatment would be of particular use in informing further systematic review and guideline development. As the body of evidence grows, homogeneity across studies will allow for quantitative meta-analysis and, ultimately, use of up-to-date methodology such as Grading of Recommendations Assessment, Development and Evaluation for the synthesis of evidence-based clinical practice guidelines.

Table 4. Summary of diversity among grouped studies

Intervention group	No. of patients	No. in study (Type)	Sources of diversity
Socks	394	2 (RCT)	Different intervention, multiple comparators, co-interventions, indirect comparisons
Antiperspirants	42	2 (RCT, NRCT)	Study design, different intervention, indirect comparisons
Barriers	316	3 (2 RCT, 1 NRCT)	Study design, different intervention, multiple comparators

RCT, randomized controlled trial; NRCT, nonrandomized controlled trial.

Acknowledgments: Mr. Mark Ingram, University of Kentucky Medical Center Library, Mr. David Rothman, SUNY Upstate Medical University, and Ms. Brandy Tuttle, Duke University Medical Center Library, for assistance with search strategy. Dr. Oscar Ortiz-Vargas for assistance with Spanish language translation. Dr. William D Grant, SUNY Upstate Medical University, and the University of Kentucky Applied Statistics Lab for guidance regarding statistical analysis.

Author Contributions: All authors contributed to study design and manuscript preparation. Drs. Worthing and Percy were responsible for independent analysis of included studies. Dr. Joslin served as mediator for any dispute.

Financial/Material Support: None.

Disclosures: None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.wem.2017.03.007>.

References

- Twombly SE, Schussman LC. Gender differences in injury and illness rates on wilderness backpacking trips. *Wilderness Environ Med.* 1995;6:363–376.
- Anderson LS Jr, Rebholz CM, White LF, et al. The impact of footwear and packweight on injury and illness among long-distance hikers. *Wilderness Environ Med.* 2009;20:250–256.
- Knapik JJ, Hamlet MP, Thompson KJ, Jones BH. Influence of boot-sock systems on frequency and severity of foot blisters. *Mil Med.* 1996;161:594–598.
- Bush RA, Brodine SK, Shaffer RA. The association of blisters with musculoskeletal injuries in male marine recruits. *J Am Podiatr Med Assoc.* 2000;90:194–198.
- Hoffman MD, Fogard K. Factors related to successful completion of a 161-km ultramarathon. *Int J Sports Physiol Perform.* 2011;6:25–37.
- Scheer BV, Reljic D, Murray A, Costa RJ. The enemy of the feet: blisters in ultraendurance runners. *J Am Podiatr Med Assoc.* 2014;104:473–478.
- Boulware DR, Forgey WW, Martin Ii WJ. Medical risks of wilderness hiking. *Am J Med.* 2003;114:288–293.
- McLaughlin KA, Townes DA, Wedmore IS, Billingsley RT, Listrom CD, Iverson LD. Pattern of injury and illness during expedition-length adventure races. *Wilderness Environ Med.* 2006;17:158–161.
- Krabak BJ, Waite B, Schiff MA. Study of injury and illness rates in multiday ultramarathon runners. *Med Sci Sports Exerc.* 2011;43:2314–2320.
- Scheer BV, Murray A. Al andalus ultra trail: an observation of medical interventions during a 219-km, 5-day ultramarathon stage race. *Clin J Sport Med.* 2011;21:444–446.
- Knapik JJ, Reynolds KL, Duplantis KL, Jones BH. Friction blisters. Pathophysiology, prevention and treatment. *Sports Med.* 1995;20:136–147.
- Patterson HS, Woolley TW, Lednar WM. Foot blister risk factors in an ROTC summer camp population. *Mil Med.* 1994;159:130–135.
- Mailler EA, Adams BB. The wear and tear of 26.2: dermatological injuries reported on marathon day. *Br J Sport Med.* 2004;38:498–501.
- Brennan H Jr., Jackson CR, Olsen C, Wilson C. Blisters on the battlefield: the prevalence of and factors associated with foot friction blisters during Operation Iraqi Freedom I. *Mil Med.* 2012;177:157–162.
- Kirkham S, Lam S, Nester C, Hashmi F. The effect of hydration on the risk of friction blister formation on the heel of the foot. *Skin Res Technol.* 2014;20:246–253.
- Quinn RH, Wedmore I, Johnson EL, et al. Wilderness Medical Society practice guidelines for basic wound management in the austere environment: 2014 update. *Wilderness Environ Med.* 2014;25:S118–S133.
- Lipman GS, Scheer BV. Blisters: the enemy of the feet. *Wilderness Environ Med.* 2015;26:275–276.
- Lipman GS, Sharp LJ, Christensen M, et al. Paper tape prevents foot blisters: a randomized prevention trial assessing paper tape in endurance distances II (Pre-TAPED II). *Clin J Sport Med.* 2016;26:362–368.
- Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med.* 2009;6:e1000100.
- Scottish Intercollegiate Guidelines Network (SIGN), . *SIGN 50: A Guideline Developer's Handbook*. Edinburgh: SIGN; 2015.
- Higgins JPT, Green SG, eds. *Cochrane Handbook for Systematic Reviews of Interventions*. Vol 5.1.0. The Cochrane Collaborations. West Sussex, UK: John Wiley & Sons; 2010.
- Schünemann H, Brożek J, Guyatt G, Oxman A, eds. *GRADE Handbook for Grading Quality of Evidence and Strength of Recommendations*. Updated October 2013 The GRADE Working Group; 2013. Available at guidelinedevelopment.org/handbook. Accessed November 21, 2015.
- Herring KM, Richie DH Jr. Friction blisters and sock fiber composition. A double-blind study. *J Am Podiatr Med Assoc.* 1990;80:63–71.
- Herring KM, Richie DH Jr. Comparison of cotton and acrylic socks using a generic cushion sole design for runners. *J Am Podiatr Med Assoc.* 1993;83:515–522.
- Jagoda A, Madden H, Hinson C. A friction blister prevention study in a population of marines. *Mil Med.* 1981;146:42–44.
- Van Tiggelen D, Wickes S, Coorevits P, Dumalin M, Witvrouw E. Sock systems to prevent foot blisters and the impact on overuse injuries of the knee joint. *Mil Med.* 2009;174:183–189.

27. Darrigrand A, Reynolds K, Jackson R, Hamlet M, Roberts D. Efficacy of antiperspirants on feet. *Mil Med*. 1992;157:256–259.
28. Knapik JJ, Reynolds K, Barson J. Influence of an antiperspirant on foot blister incidence during cross-country hiking. *J Am Acad Dermatol*. 1998;39:202–206.
29. Reynolds K, Darrigrand A, Roberts D, et al. Effects of an antiperspirant with emollients on foot-sweat accumulation and blister formation while walking in the heat. *J Am Acad Dermatol*. 1995;33:626–630.
30. Lipman GS, Ellis MA, Lewis EJ, et al. A prospective randomized blister prevention trial assessing paper tape in endurance distances (Pre-TAPED). *Wilderness Environ Med*. 2014;25:457–461.
31. Tan SSW, Swee KK, Lim JKY. Efficacy of a new blister prevention plaster under tropical conditions. *Wilderness and Environ Med*. 2008;19:77–81.
32. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. *Ann Intern Med*. 2010;152:726–732.