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Uptake of permethrin from impregnated clothing

Bernd Rossbach[a,*], Klaus E. Appel[b], Klaus G. Mross[c], Stephan Letzel[a]

[a] University Medical Center of the Johannes Gutenberg University Mainz, Institute for Occupational, Social, and Environmental Medicine, Obere Zahlbacher Strasse 67, 55131 Mainz, Germany
[b] Federal Institute for Risk Assessment, Thielallee 88-92, 14195 Berlin, Germany
[c] Bundeswehr Regional Medical Command II, Occupational Medicine, Schloss Oranienstein, 65582 Diez, Germany

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ABSTRACT

In order to examine exposure and health risks which can arise from permethrin-impregnated clothing, a controlled trial was conducted. In a study group consisting of 187 volunteers in total, a subgroup of 86 persons was equipped with permethrin-impregnated battle dress uniforms (BDU) for 28 days. One hundred and one persons served as a control group, wearing non-impregnated BDUs throughout the entire study period of 56 days. Internal exposure of all participants was assessed by determination of urinary permethrin metabolites (cis-DCCA, trans-DCCA and 3-PBA) on day 0, 14 and 28 of the wearing period and 28 days after termination of wearing.

Exposure levels in the control group ranged within background exposure of the general German population at all four dates of sampling (medians Σ DCCA + 3-PBA were 0.09, 0.13, 0.23 and 0.10 μg/l, respectively). For the group equipped with impregnated BDUs this applied to day 0 (0.31 μg/l) only, while the following measurements revealed considerably higher metabolite concentrations (31.39, 22.01 and 1.44 μg/l, respectively), especially while wearing impregnated clothing.

Due to these results a substantial uptake of permethrin from impregnated BDUs has to be assumed. However, since calculations reveal a maximum permethrin uptake clearly below the acceptable daily intake (ADI), health impairments are rather unlikely.

1. Introduction

Because of limited options concerning vaccination, chemoprophylaxis or therapy, prevention of exposure to arthropods plays a crucial role in preventing many arthropod-borne diseases. For persons at risk (e.g. outdoor workers, soldiers or travellers) the use of a topical repellent in combination with residual insecticides which can be impregnated into clothing, tents or netting is considered an effective preventive measure (Rozendaal, 1997; WHO, 2001a,b).

The pyrethroid insecticide permethrin is usually used for impregnating fabric. As an active ingredient, this compound combines repellence, hot-feet, knockdown, kill and residual activity to a broad range of arthropods (Young and Evans, 1998). Though being a potent neurotoxin to insects, the mammalian toxicity of permethrin is considered to be low, promoting its widespread use for pest control in veterinary and human medicine (WHO, 2005, for review on toxicology see also ATSDR, 2003; Appel et al., 2008).

Impregnation of clothing with permethrin can be achieved through various methods. Conventional impregnation techniques comprise spraying with or immersion in permethrin solutions, entailing problems like patchy distribution of the active ingredient, considerable loss of activity after laundering, or users' exposure to treatment solutions (Faulde et al., 2003). To avoid such difficulties, a factory-based impregnation technique has recently been developed, which includes coating of the fabric with a permethrin containing polymer before tailoring (Faulde et al., 2006; Faulde and Uedelhoven, 2006).

No matter which technique is used, it has to be ensured that wearing of permethrin-impregnated clothing does not entail additional health risks for the user. To assess the potential risk, data on migration of permethrin from the impregnated material to the body surface as well as on uptake of permethrin into the body is needed. Besides model calculations, which have been conducted in the past for immersion impregnated clothing (NRC, 1994), particularly human biological monitoring (biomonitoring) offers the chance to quantify an uptake of permethrin from impregnated clothing as exposure source.

Due to this, extensive human biomonitoring studies have been conducted after supplying soldiers of the German Federal Armed Forces (Bundeswehr), who were deployed to high-risk areas for vector-associated diseases, with factory-based permethrin-impregnated battle dress uniforms (BDUs). In addition to research

* Corresponding author at: University Medical Center of the Johannes Gutenberg University Mainz, Institute for Occupational, Social, and Environmental Medicine, Obere Zahlbacher Straße 67, 55131 Mainz, Germany. Tel.: +49 6131 3930279; fax: +49 6131 3930280.
E-mail address: rossbach@uni-mainz.de (B. Rossbach).

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on deployed personnel (Rossbach et al., 2005; Scharnbacher et al., 2006), a controlled study was conducted among domestic personnel. One objective of this study was to compare internal permethrin exposures, under controlled conditions, among volunteers wearing impregnated BDUs on the one hand and participants wearing conventional non-impregnated BDUs on the other hand. The urinary excretion of permethrin metabolites was used as a biomarker of internal exposure. Apart from allowing comparison of groups, this approach also enabled a quantitative estimation of permethrin uptake which can be useful for risk assessment.

2. Materials and methods

2.1. Study group

The study was conducted between February and April 2005 at two military bases in Germany. All participants were healthy soldiers of the German Federal Armed Forces (Bundeswehr) and participated in the study voluntarily. The study population consisted of two groups of soldiers at each location wearing either conventional, non-impregnated or factory-based permethrin-impregnated BDUs for 28 days during daily office hours. Permethrin content in BDUs, according to Faulde et al. (2006), was 1.300 mg/m^2 (cis/trans ratio 25:75). Members of both subgroups had similar job functions and working areas, fulfilling administrative (location 1) or typical military (location 2) tasks. The average wearing period of impregnated BDUs was 50.7 h/week and ranged from 40 to 72 h/week. Further description of the study population is given in Table 1.

General personal data (age, sex, body weight, etc.) and other factors influencing internal pyrethroid exposure (e.g. duration of BDU wearing, domestic use of insecticides, dermal application of pyrethroid containing drugs) were obtained through a self-administered questionnaire. Prior to the study all participants gave their informed consent. The study was conducted according to the ethical principles of the Declaration of Helsinki. The protocol was approved by the local ethics committee.

Table 1
Participant data.

	BDU conventional	BDU impregnated	Total study population
Number (n)	101	86	187
Female (%)	8 (7.9)	9 (10.5)	17 (9.1)
Age [years]			
Median	23	25	24
Range	18–58	17–56	17–58
BMI [kg/m^2]			
Median	24.5	24.7	24.6
Range	19.2–34.3	17.8–30.6	17.8–34.3

2.2. Assessment of internal exposure

In order to determine internal pyrethroid exposure, morning spot urine samples were collected from all subjects at four points in time throughout the study. Samples were taken immediately before the beginning of the wearing period (day 0), after 14 days of wearing (day 14), at the end of the wearing period (day 28) and 28 days after termination of the wearing period (day 56). All samples were frozen after collection and stored at −20 °C until analysis.

Internal pyrethroid exposure was assessed by measuring urinary concentrations of the pyrethroid metabolites cis- and trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane-1-carboxylic acid (cis-DCCA and trans-DCCA) and 3-phenoxybenzoic acid (3-PBA), which are the main metabolites of perme-

Table 2
Urinary metabolite concentrations in relation to date of sampling and type of BDU (conv.: conventional, imp.: permethrin-impregnated, P50: median, P95: 95th percentile).

		cis-DCCA	trans-DCCA	3-PBA	Σ DCCA + 3-PBA
Day 0 (before wearing)					
BDU conv.	n < LOD	67	29	26	–
n = 88	Range [μg/l]	<0.03–1.03	<0.03–2.49	<0.02–2.70	0.04–6.21
	P50 [μg/l]	<0.03	0.05	0.03	0.09
	P95 [μg/l]	0.09	0.18	0.14	0.35
BDU imp.	n < LOD	27	9	6	–
n = 66	Range [μg/l]	<0.03–4.07	<0.03–21.02	<0.02–6.48	0.04–31.57
	P50 [μg/l]	0.04	0.16	0.11	0.31
	P95 [μg/l]	0.28	1.07	0.65	1.94
p (Mann–Whitney)	<0.0001	<0.0001	<0.0001	<0.0001	
Day 14 (after 14 d of wearing)					
BDU conv.	n < LOD	41	16	12	–
n = 79	Range [μg/l]	<0.03–0.43	<0.03–2.30	<0.02–0.99	0.04–3.72
	P50 [μg/l]	<0.03	0.06	0.04	0.13
	P95 [μg/l]	0.07	0.35	0.23	0.65
BDU imp.	n < LOD	0	0	0	–
n = 68	Range [μg/l]	0.05–10.49	0.17–87.56	0.09–43.92	0.31–140.78
	P50 [μg/l]	2.19	18.51	10.11	31.39
	P95 [μg/l]	8.47	81.92	40.08	131.05
p (Mann–Whitney)	<0.0001	<0.0001	<0.0001	<0.0001	
Day 28 (end of wearing period)					
BDU conv.	n < LOD	25	5	6	–
n = 72	Range [μg/l]	<0.03–1.08	<0.03–5.63	<0.02–3.55	0.04–10.25
	P50 [μg/l]	0.04	0.10	0.08	0.23
	P95 [μg/l]	0.16	0.49	0.47	1.15
BDU imp.	n < LOD	1	1	0	–
n = 63	Range [μg/l]	<0.03–18.13	<0.03–128.74	0.02–65.46	0.05–212.33
	P50 [μg/l]	1.47	11.87	6.64	22.01
	P95 [μg/l]	10.79	64.52	42.19	116.47
p (Mann–Whitney)	<0.0001	<0.0001	<0.0001	<0.0001	
Day 56 (28 d after wearing)					
BDU conv.	n < LOD	33	19	9	–
n = 52	Range [μg/l]	<0.03–0.75	<0.03–4.08	<0.02–2.54	0.04–7.38
	P50 [μg/l]	<0.03	0.05	0.04	0.10
	P95 [μg/l]	0.49	1.55	1.18	3.22
BDU imp.	n < LOD	2	0	0	–
n = 55	Range [μg/l]	<0.03–2.19	0.12–11.27	0.10–6.67	0.23–20.13
	P50 [μg/l]	0.18	0.73	0.53	1.44
	P95 [μg/l]	1.31	9.25	5.57	16.12
p (Mann–Whitney)	<0.0001	<0.0001	<0.0001	<0.0001	