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Acceptance of semipermeable glove liners compared to cotton glove liners in health care workers with work-related skin diseases: Results of a quasi-randomized trial under real workplace conditions

This paper is dedicated to the memory of Dr. Meike Strunk, active co-author of this paper, mentor, colleague and friend who passed away unexpectedly on 28th February 2020.

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Abstract

Background: Glove liners (GLs) made of cotton (COT) are worn under impermeable gloves to prevent occlusion effects. Semipermeable GLs made of Sympatex (SYM) might be an alternative.

Objectives: To evaluate the acceptance of GLs (COT/SYM) in health care workers (HCWs) with work-related skin diseases (WRSDs).

Methods: 161 HCWs with WRSDs were asked to wear GLs in combination with occlusive gloves for 10 +/- 2 weeks under workplace conditions. A questionnaire was applied to compare acceptance and usability of the respective glove combinations and previously used protective gloves (PUGs).

Results: A total of 120 data sets were available (SYM: n=65, 77.4%; COT: n= 55, 71.4%). Both GLs provided a significantly lower sweating sensation, more pleasant climate, comfortable wearing experience and moist or dry feeling on the skin compared to PUGs. SYM-GLs performed significantly better than COT-GLs regarding mobility of hands, sensitivity and sense of touch. COT-GLs were significantly better than SYM-GLs in the categories fit, donning and doffing and material contact.

Conclusions: Both GLs did not impair work performance, were applicable in various areas of health care activities and were preferred over PUGs. Our results indicate that SYM-GLs are an alternative to COT-GLs and thus, may contribute to current prevention strategies.

Keywords: Liners; Occlusion; Sympatex; Membrane, semipermeable; Workplace; Cotton; Skin diseases; Gloves, Protective; Health Personnel; Eczema

1 | Introduction

Health care workers (HCWs) are at risk of developing work-related skin diseases (WRSDs) primarily due to a high amount of wet work and repeated exposure to irritants (e.g. cleansers, detergents and disinfectants).^{1,2} The most common WRSD is hand eczema with a 1-year prevalence of about 20% in HCWs.^{3,4} Wearing of protective gloves is mandatory in health care to avoid exposure to occupational hazards, including pathogenic germs.⁵⁻¹⁰ These gloves usually consist of (water-)impermeable materials (rubber or plastic) which induce occlusion effects by inhibiting the evaporation of skin moisture and by heat accumulation. A recent review stated that especially long-term occlusion, extensive wearing of gloves (6 hrs/day for >10 days), additional exposure to hazardous substances as well as occlusion of pre-irritated skin may lead to severe impairment of the epidermal barrier function.¹¹ Glove liners (GLs) are defined as a separate glove-like hand covering made of cotton (COT) or other natural (e.g. wool) or synthetic fibers with different material strength/thickness. They are recommended to be worn underneath occlusive protective gloves in case of "long" wearing times or activities lasting > 10-15 minutes to counteract effects of glove occlusion.^{6,7,12-14}

Textile GLs absorb moisture by a hygroscopic effect. Moreover, gloves made of COT are used in patients with hand lesions as cover or support of topical treatment. However, studies evaluating the use of GLs are scarce. In a few intervention studies based on health education, the use of COT-GLs were recommended as part of complex programs developed for primary or secondary prevention of WRSDs in high-risk occupations, but their practicability or effectiveness were not evaluated separately.¹⁵⁻¹⁸

GLs made of semipermeable synthetic materials might be an alternative to COT-GLs. They enable permeation of moisture (vapour of human sweat) along the diffusion gradient on a molecular level. Moisture remains in the gap between the semipermeable GL and the impermeable protective glove and leaks out via the cuff by movements of the hands during glove use. Investigations conducted with the semipermeable Gore-Tex membrane (W. L. Gore and Associates, Unterföhring, Germany) focused on its effects as wound dressing,¹⁹ on skin barrier regeneration after irritation²⁰⁻²² and prevention of allergic contact dermatitis to rubber accelerators^{23,24}. Previous experimental and small-scale cohort studies under real workplace conditions of our research group showed that the 15 µm thin semipermeable polyester-polyether Sympatex (SYM) membrane (Sympatex Technologies GmbH, Unterföhring, Germany) reduces occlusion effects of impermeable protective gloves and prevents skin barrier impairments.²⁵⁻²⁸ The results indicated a cross-occupational suitability of SYM-GLs with regard to user acceptance (especially tactility and sweating sensation) and a preference over previously used protective gloves or glove combinations.^{28,29} However, similarly to the COT-GLs, no systematic

evaluations have yet been carried out for GLs made of semipermeable materials with regard to their acceptance in everyday work.

Therefore, the aim of this study was to determine the user acceptance of SYM-GLs in direct comparison to COT-GLs and to answer the following research questions: (i) For which activities are GLs suitable? (ii) How does the use of occlusive gloves in combination with either SYM or COT-GLs differ from the use of occlusive gloves without GLs? (iii) Are there differences in the usability of SYM and COT-GLs?

2 | Methods

2.1 Participants and recruitment

From February to October 2016, HCWs with WRSDs were consecutively recruited while taking part in a secondary individual prevention programme (SIP)^{30,31} at the Institute for Interdisciplinary Dermatological Prevention and Rehabilitation at the University of Osnabrück (iDerm) or in one of six Education and Support Centers (Schulungs- und Beratungszentrum [schu.ber.z]) of the Institution for Statutory Accident Insurance and Prevention in the Health and Welfare services (BGW) throughout Germany (Hamburg, Delmenhorst, Berlin, Mainz, Karlsruhe, Wuerzburg). All participants were voluntarily taking part in these free-of-charge seminars financed by the BGW. Inclusion criteria are shown in Table 1. As part of the SIP, the HCWs received health education and counseling regarding personal protective measures, including selection of appropriate protective gloves. Prior to the start of recruitment the involved health educators of our institution and the six schu.ber.z took part in a standardized multiplier training and received comprehensive written instructions (manual) on the study procedures.

2.2 Study design and materials of glove liners

For this cross-sectional study, the participants were assigned to one of the two study cohorts according to a randomised scheme determined in advance by the study coordination. Recruitment alternated weekly for the SYM cohort and the COT cohort; in half of the centers recruitment alternated in reverse order. Accordingly, entire seminar groups of HCWs were equipped with either COT or SYM-GLs in alternation to avoid cross-contamination by communication between participants. During the SIP, the participants tested the GLs to ensure a good fit when wearing them underneath the selected occlusive protective gloves. Each study participant received 50 pairs of COT-GLs (multiple use, washable) or 256 pairs of SYM-GLs (single use, not washable) including detailed instructions describing the specific use and care of the GLs. Participants were advised to use GLs when performing work tasks with occlusive protective gloves lasting > 10-15 minutes. Table 2 and Figures 1 and 2 provide detailed information on the GLs.

All investigations were performed in accordance with the ethical principles for medical research involving human subjects documented in the World Medical Association Declaration of Helsinki³². All participants gave written informed consent. The study was approved by the Ethics committee of the University of Osnabrück (reference 46/9).

2.3 Questionnaire

After the 3-months application phase, all study participants were asked to fill out an anonymous modularized questionnaire which were sent to the participants by mail including a cover letter and a prepaid return envelope. In case of non-response, two reminders were sent at intervals of one month. The study lasted until March 2017, including the follow-up period.

The questionnaire included the standardized recording of socio-demographic characteristics (e.g. age, gender, occupation) and an evaluation of the wearing behavior of the GLs with regard to various variables. The participants were asked to rate the practicability for the activity they most frequently performed with the GL during the study period, and to compare the newly tested glove combination with the gloves or glove combinations they previously used (PUG) to use for this activity. In the first step, several statements were evaluated according to a 5-point Likert scale for agreement/satisfaction (1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, 5 = strongly disagree) (e.g. "The climate under the gloves is pleasant.") (Table 5). The basis of the final evaluation (e.g. "sweating sensation") was a 6-point scale based on the German school grading system consisting of six numerical grades (1: very good, 2: good, 3: satisfactory, 4: sufficient, 5: poor, 6: very poor) (Table 6). We chose this scale because all participants are familiar with these categories. In addition, the respondents were asked to rate their own skin condition at the beginning (retrospectively) and the end of the test phase on a 10-level scale (0 = none, 10 = severe skin changes).

2.4 Data analysis

Statistical analyses were performed with SPSS for windows, version 24.0 (RRID:SCR_002865, IBM Corp., Armonk, NY). Results of descriptive data analysis are shown as percentages (%) and mean values (M). Parametric tests were used for statistical analyses of metric variables. Paired t-tests were applied for comparing the newly tested glove combinations (either SYM-GL or COT-GL in combination with protective gloves) and the previously used protective gloves [PUGs]. If COT-GLs had been used prior to participation in the application study, the PUG scores were not included in the analyses and were treated as missing values (n=7). This means that whenever PUG is mentioned, PUG without GLs are meant. Unpaired t-tests were applied for comparing results for SYM-GL and COT-GL and for drop-out analyses. A P value of < .05 was considered to be statistically significant.

3 | Results

3.1 Sample / Demographics

A total of 161 participants were recruited to test the GLs made of SYM (n=84) or COT (n=77) underneath occlusive protective gloves over a period of 10 +/- 2 weeks in everyday working life. 138 (85.7%) questionnaires were returned, among them 75 (89.3%) from the SYM cohort and 63 (81.1%) from the COT cohort. Only participants who had completed at least eight weeks of wearing the respective GLs were included in the analyses. Persons with less than 8 weeks of test duration or with unknown test duration due to missing data in the questionnaire (n=18) as well as those who did not return the questionnaire (n=23) were excluded. This led to a reduction of the analyzed study sample (120 participants [74.5%]; SYM: n=65, 77.4%; COT: n=55, 71.4%) but to an improved comparability of data. Table 3 shows the participants' characteristics in detail.

Most of those who returned the questionnaire but indicated that they had not tested the GLs for at least 8 weeks, provided a reason (multiple reasons possible). In the SYM cohort (n=10/75), 8 gave the following reasons: no practicability of GL use ([too] high time consumption, [too] short glove wearing intervals; n=3), holiday/vacation (n=2), sick leave (n=2), move (n=1), stress (n=1) and forgetfulness (n=1). In the COT cohort (n=8/63), the following reasons were given: improvement of skin condition (n=2), lack of sensitivity (n=2) and other (holiday, deterioration of skin condition, absenteeism from work due to pregnancy, no need, sick leave, lack of support at the workplace/no permission from the employer to use COT-GLs, laziness; each n=1).

In order to exclude systematic distortions in the sample, a drop-out analysis was performed regarding gender, age and occupation which were the only variables collected during initial recruitment. No significant differences were found between drop-outs and those who tested the GLs for at least 8 weeks within the SYM cohort (n=10 vs. 65) and the COT cohort (n=8 vs. 55) with regard to gender, age and occupation.

3.2 Application and frequency of use / Practicability regarding different tasks

Both SYM (62/64, 96.9%) and COT (55/55, 100%) GL were mainly used in combination with disposable protective gloves. The average daily consumption for SYM-GLs was 9.0 pairs (2-25 pairs/day; n=61) and for COT-GLs 4.6 pairs (1-15 pair[s]/day; n=38). Most participants (SYM: n=63, 87.3%; COT: n=54, 88.3%) confirmed that the (new) glove combination did not impair their ability to perform their work activities. The work activities most frequently reported to be performed with GLs were similar in both groups (Table 4).

3.3 Rating of properties of gloves

Sympatex-combination vs. previously used protective gloves

Use of SYM-GLs received a significantly better rating for "sweating sensation" compared to PUGs ($P < .001$). Also, "climate" ($P < .001$), "glove material" ($P < .001$), "moisture and dryness sensation" (each $P < .001$) and "comfortable wearing experience" ($P = .053$) were found to be significantly more pleasant when using SYM-GLs. For the parameters „fit“ ($P = .016$), "donning and doffing" ($P = .008$) and "appearance" (n.s.), PUGs were rated better (Table 5/6).

Cotton-combination vs. previously used protective gloves

Use of COT-GLs received better ratings for "wearing comfort" ($P < .001$), "sweating sensation" ($P < .001$), and "suitability for daily use" ($P = .005$) compared to PUGs. Also, "climate" ($P < .001$), "glove material" ($P < .001$), and "moisture and dryness sensation" (each $P < .001$) were found to be significantly more pleasant when using COT-GLs. With regard to the aspects of "donning and doffing", a superiority over PUGs (n.s.) was shown. With regard to the test parameter "sensitivity" ($P < .001$), "touch" ($P < .001$) and "agility", PUGs were rated better (Table 5/6).

Cotton-combination vs. Sympatex-combination

In the categories "mobility of hands/fingers" ($P = .022$), "sensitivity" ($P = .003$) and "sense of touch" ($P < .001$), SYM-GLs scored significantly better than COT-GLs. Sweating sensation was better underneath SYM-GLs than COT-GLs (n.s.). SYM-GLs scored better than COT-GLs regarding "dry skin feeling even when wearing gloves for a long time" ($P = .006$). With regard to "fit" ($P < .001$) and "donning and doffing" ($P < .001$), "fit of material" ($P < .001$) and "appearance" ($P = .016$), COT-GLs performed significantly better than SYM-GLs. There were no statistically significant differences with regard to "suitability for everyday use" and "wearing comfort" between SYM and COT-GLs. (Table 5/6) Both the COT and the SYM-GLs combinations were rated as "good" ($M = 2.3$) in the overall evaluation (n.s.). Also, most individual categories (e.g. sweating) were rated "good" for both GLs (Table 6).

3.4 Skin condition

On average, participants of the SYM cohort ($n=65$) retrospectively rated their own skin condition (on the 10-point scale) as 5.4 at inclusion and as 3.3 at the end of the study ($\Delta=2.1$) ($P < .001$). The participants of the COT cohort rated their skin condition retrospectively as 5.9 ($n=54$) at inclusion and as 2.9 ($n=53$) at the end of the study ($\Delta=3.0$) ($P < .001$). In addition, 78.0% ($n=46$) of the SYM and 85.9% ($n=45$) of the COT cohort stated that this self-reported improvement of the skin condition could be at least partially attributed to the use of GLs.

3.5 Usability and glove type preferences

The "suitability for daily use" of both GLs was found to be "good" (Table 6). More than two thirds of the respondents in both cohorts stated that they were in favor of the routine use of the respective GLs at work (SYM: n=65, 76.9%; COT: n=53, 75.5%; n.s.), would recommend the respective GLs to others (SYM: n=65, 86.2%; COT: n=54, 92.6%; n.s.) and would also use them for domestic activities (SYM: n=65, 70.8%; COT: n=54, 92.6%; $P = .004$).

4 | Discussion

To the best of our knowledge, this is the first application study comparing the use of GLs made of COT or a semipermeable membrane under real working conditions. In terms of wearability in everyday working life and suitability for everyday use, both GLs received good ratings in this cohorts of HCWs with WRSDs suggesting that their use underneath occlusive gloves is not a disadvantage. On the contrary, most items in terms of user acceptance were rated better compared to the use of protective gloves without GLs. A big majority in both groups reported that they were able to perform everyday occupational activities as usual when wearing the GLs (SYM: 87.3%; COT: 88.3%).

Both types of GLs were frequently used in typical occupation-specific activities, such as basic care in hospital/geriatric nurses, massages in physiotherapists and chairside assistance in dental assistants. This was in line with other studies showing a good general acceptance of textile³³⁻³⁵ and semipermeable³³ GLs. The average daily consumption of SYM-GLs with 9.0 pairs/day was significantly higher than in the COT cohort with 4.6 pairs/day ($P < .001$). This suggests that COT-GLs were – against our study instructions – worn more than once while SYM-GLs were used only once as instructed, raising obvious hygiene issues in hospital settings for COT-GLs.

4.1 Climate conditions

The use of GLs made of either SYM or COT underneath occlusive gloves was rated superior to the use of occlusive gloves without GLs regarding all climatic parameters. COT-GLs absorb moisture caused by sweating whereas SYM-GLs enable permeation of moisture caused by sweating along the diffusion gradient to the outer side of the membrane³⁶. Thus, both mechanisms reduce moisture accumulation within occlusive gloves. Accordingly, the results of the present study indicate that GLs keep the hands dry(er) even when occlusive gloves are worn for long periods and reduce the feeling of moisture and uncomfortable warmth underneath occlusive gloves. The sweating sensation was lower for both types of GLs compared to PUGs without GLs despite the second glove layer. This is consistent with data from a 5-day half-side wear test of SYM-GLs in employees from different occupational areas (n=72).²⁹ In that study, a more pleasant skin climate and reduced sweating sensation was reported for the use of SYM-GLs underneath occlusive gloves compared to wearing occlusive gloves without the GLs. Also others

found reduced sweating sensation under a single semipermeable glove compared to impermeable glove models in short-term wearing trials.^{25,26} The results of these studies were corroborated by skin bioengineering and are consistent with the study by Sonsmann et al.²⁸ In the present study, the sensation of sweating, climate and feeling of dry skin (even when wearing occlusive gloves for a long time) were rated better for SYM-GLs than COT-GLs. In line with this, participants in the study by Baack et al. also indicated a cooler and drier feeling with less itching for wearing of semipermeable GLs compared to COT-GLs.³³ Hygroscopic natural COT fibers are known for their water absorption capacity, but also for their swift material saturation. Therefore, the use of COT-GLs in comparison to SYM-GLs seems more appropriate for a shorter duration of wearing occlusive gloves, since longer wearing times lead to an exhaustion of the moisture-reducing effect of COT. Thus, SYM-GLs may be superior to COT-GLs when long continuous glove wearing is necessary.

4.2 Skin feel and wearing comfort

The wearing comfort and material feel on the skin was rated significantly better for use of both types of GLs underneath occlusive gloves than PUGs worn without GLs. All study participants reported an improvement of their skin condition over the study period. In a small preliminary study by Hübner et al. which examined the use of COT-GLs in medical staff (n=18) of an intensive care unit over a 3-months period, the wearing comfort of COT-GLs was predominantly perceived as (very) pleasant (43.7%).³⁴ Other studies have also shown that COT-GLs are beneficial for maintaining a good skin condition and comfort.^{34,35,37} There were no significant differences between use of SYM and COT-GLs in terms of wearing comfort and material feel on the skin. In direct comparison, however, a higher share of participants in the COT group attributed the improved skin condition (in part) to the use of GLs. However, this difference was not significant. In contrast, Baack et al. found a preference of semipermeable over COT-GLs in terms of hand comfort and skin comfort.³³ Further prospective studies are needed to explore the tolerability of GLs in patients with hand dermatoses. Since GLs may be in direct contact with the skin for a long time of the day, it is important to carefully choose suitable materials, in particular for subjects who (already) have impaired skin.³⁸ Neither COT or SYM have so far been identified as containing allergens, so that direct skin contact with damaged skin is considered unproblematic from an allergological perspective. Notably, skin bioengineering studies showed a regenerative potential of textile and semipermeable GLs on irritated skin, which could also be beneficial for patients with skin lesions of the hands (Heichel et al., in preparation).^{26-28,39,40}

4.3 Mobility and tactility / fine motor skills

The function of the hands could already be impaired by wearing the protective glove alone.^{41,42} Therefore, GL should ideally not further decrease sensory and motor functions of the hands.

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Impairments of hand mobility (e.g. when executing targeted movements) and sensitivity were exclusively indicated by the participants for the use of COT-GLs underneath occlusive gloves compared to PUGs without GLs. This is in line with other studies showing a better tactility for semipermeable gloves compared to COT-GLs.^{33,39} The lower tactility is probably related to the thick material of COT-GLs which impairs activities for which a high tactility or a firm grip is required^{37,43-46}. In contrast, SYM-GLs have an approximately 5x lower material thickness of 15 μm than COT-GLs. Furthermore, tactile properties of textile GLs are negatively influenced by circumferential seams,^{47,48} which is why COT-GLs should ideally be round-knitted rather than woven and sewn^{34,49}. The present results are consistent with those of the study in HCWs of an intensive care unit by Hübner et al., in which the sense of touch was rated predominantly "satisfactory" (47.9%) when wearing COT-GLs and predominantly "good" (58.3%) when using protective gloves without COT-GLs.³⁴ In that study, GL were preferably worn for activities where tactility/sensitivity were of minor importance (86.8%), e.g. positioning or mobilization of patients and general activities on the patient.³⁴ Activities which required higher fine motor skills were rarely performed with GLs (3%), e.g. treatment procedures involving change of wound dressings.³⁴ As the majority of occupational activities performed by HCWs require a high degree of sensitivity/tactility, the use of SYM-GLs may be superior to the use of COT-GLs. However, regular practice with GLs may lead to habituation and reduce the noticeable impairment of manual dexterity or tactile sensation. This "habituation effect" has already been demonstrated in studies on double-gloving of occlusive protective gloves.⁵⁰ If there are still restrictions in tactility, use of fingertip-free or completely fingerless cotton gloves can be considered.^{34,51,52} However, these cannot counteract negative occlusion effects at the fingers or fingertips.

4.4 Fit, appearance, donning and doffing

The SYM glove received significantly lower rates compared to PUGs regarding fit and appearance which corresponds to a previous study²⁹. No significant differences were found between COT-GLs and PUGs. In direct comparison, the SYM-GLs was rated lower than the COT-GLs in terms of fit, which can be explained by the two-dimensionality of the SYM-GLs. A tight-fitting protective occlusive glove worn on top of the SYM glove can take on a formative function (influence the fit).²⁶ Since the SYM glove is used exclusively as a GL, also the worse rating of the appearance plays a subordinate role. The donning and doffing behavior of occlusive gloves in combination with SYM-GLs was rated significantly lower compared to PUGs without GLs, while use of COT-GLs scored better compared to PUGs without GLs. In addition, the "donning and doffing" behaviour of SYM-GLs was rated significantly worse compared to COT-GLs. The COT material of the GLs prevents adherence of the protective glove to moist skin which facilitates putting on the protective gloves in everyday work. Also, in the study by Hübner et al., putting on and taking off COT-GLs was considered unproblematic.³⁴ The additional time required was

classified as low (58.3%) or not perceived (12.5%). In contrast, the polyester-polyether SYM membrane generates more friction under protective gloves (e.g. made of nitrile), which may render it more difficult to put on the protective gloves. Reasons for the problems with SYM-GLs given in the free text fields included difficulty of sticking of the glove cuff (n=6) or presence of moist hands (e.g. due to sweating, previous creaming, cleansing or disinfection) (n=4) when putting on gloves (- contrary to our clear instructions given to the participants prior to the study to use GLs only on dry skin).

Limitations

The study was conducted in HCWs suffering from WRSDs who likely have a distinct skin protection behavior or a specific motivation to implement new skin protection measures (e.g. use of GLs). Therefore, the results cannot be transferred to HCWs without WRSDs or other occupational groups. Since some of the participants had already used textile GLs prior to the study, the evaluations of the GLs in the study cannot be considered completely detached from these previous experiences. Moreover, self-reported data may be incorrect and may contain several potential sources of bias, e.g. selective memory. Some participants dropped out of the study because they indicated that they had not tested the GLs for at least 8 weeks. This may have led to selection bias overestimating the benefits of GLs. However, mainly practical reasons, often not related to the GLs themselves, were given and the drop-out analysis did not reveal major differences to the participants included in the analyses.

Conclusion

Use of GLs made of either COT or SYM were suitable in HCWs with WRSDs for various occupation-specific activities and preferred to the use of occlusive gloves without GLs. SYM-GLs were rated superior to COT-GLs with regard to moisture and tactility/mobility of the hands which are important acceptance criteria in professional practice. This suggests that SYM-GLs are a reasonable alternative to COT-GLs contributing to and expanding strategies for prevention of WRSDs. The choice of material of GLs may depend on occupation-specific requirements for the performed tasks and individual needs and preferences of the user. Our study reveals options for the new concept of semipermeable GLs. Further studies in other high-risk professions for WRSDs under real workplace conditions are required to better understand the potential benefits of different GLs as well as issues in terms of economic (e.g. costs) and environmental (e.g. sustainability) considerations and hygiene at workplaces.

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Tables

Table 1: Inclusion criteria

Inclusion criterion
▪ Insured under scheme of the Statutory Accident Insurance and Prevention in the Health and Welfare services body (BGW) ▪ Age between 18 and 55 years ▪ Regular performance of work activities that are associated with occlusive glove wearing ≥ 15 minutes ▪ No interruption of work (e.g. vacation) for more than two weeks in the 3-months study period ▪ No pregnancy ▪ Willingness and possibility to wear the glove liners daily during the 3-months study period ▪ Informed written consent and completed registration form ▪ Sufficient knowledge of the German language

Table 2: Information about the glove liners made of Sympatex and cotton

	Sympatex glove liners (SYM-GLs)	Cotton glove liners (COT-GLs)
Product and manufacturer	“Sympatex glove” (prototype) (Figure 1) Sympatex Technologies GmbH, Unterföhring, Germany	“Maximo cotton glove” (Figure 2) MaxiMo, Strickmoden Bruno Barthel GmbH & Co.KG, Chemnitz, Germany
Material	polyester-polyether (copolymer)	100% cotton (cellulose)
Material strength	15 μm	about 75 μm
Sizes and colour	XS to XXL (long cuff); white	Kids size: 6 and 8 (short cuff); adults / normal sizes: 7 to 11 (short and/or long cuff); white
Category and marking	▪ PPE Category 1 (Personal Protective Equipment) in accordance with the PPE Directive (since April 2020) ▪ Oeko-Tex® Standard 100	▪ PPE Category 1 in accordance with the PPE Directive, 89/686/EEC; medical support product ▪ Oeko-Tex® Standard 100

Table 3: *Participants' characteristics*

	Sympatex (SYM) cohort	Cotton (COT) cohort
Samples, n	84	77
Returned questionnaires, n (%)	75 (89.3)	63 (81.1)
Analysed samples, n (%)	65 (77.4)	55 (71.4)
Females, n (%)	61 (93.8)	50 (90.9)
Age in years, mean $\pm$ SD	36.7 $\pm$ 10.1	39.1 $\pm$ 11.6
Occupation, n (%)	▪ hospital/geriatric nurse: 29 (44.6) ▪ physiotherapist: 19 (29.2) ▪ dental assistant: 9 (13.8) ▪ other (e.g. doctor's assistant, masseur, medical laboratory technician): 8 (12.3)	▪ hospital/geriatric nurse: 28 (51.9) ▪ physiotherapist: 16 (29.6) ▪ dental assistant: 2 (3.7) ▪ other (e.g. dietary assistant, ergotherapist, midwife): 8 (14.8)

SD = standard deviation

Table 4: Work activities for which the Sympatex (n=65) or cotton (n=55) gloves liners were most frequently used

Occupation	Activities	SYM [n]	COT [n]
Hospital/geriatric nurses SYM: n=29 (44.6%) COT: n=28 (51.9%)	basic care (e.g. washing, positioning/storage, incontinence care, assistance with toilet visits)	26	21
	treatment (e.g. changing bandages, placing medication)	3	4
	cleaning / instrument preparation / surface disinfection / sterilization	2	4
	housekeeping	1	-
	food exposure (e.g. food preparation)	-	1
	unspecified / other (e.g. laboratory work, wet work, work on patients, nursing work, endoscopy assistance)	3	6
Physiotherapist SYM: n=19 (29.2%) COT: n=16 (29.6%)	massage	12	11
	lymphatic drainage	3	5
	other / further physiotherapeutic activities (e.g. positioning/storage, manual therapy, physiotherapy, breathing therapy, ice therapy, embrocations)	8	10
	housekeeping	-	1
	unspecified / other (e.g. wet work)	1	-
Dental assistant SYM: n=9 (13.8%) COT: n=2 (3.7%)	Dentist's assistance (e.g. treatment)	6	2
	cleaning / instrument preparation / surface disinfection / sterilization	2	2
	prophylaxis / dental cleaning	3	-
	unspecified / other (e.g. laboratory activity, treatment)	3	-
other (e.g. doctor's assistant, masseur, medical laboratory technician) SYM: n=8 (12.3%) COT: n=8 (14.8%)	basic care	1	1
	housekeeping (e.g. washing up, wiping, dishwasher)	2	-
	massage	1	-
	cleaning / instrument preparation / surface disinfection / sterilization	-	1
	Other / further physiotherapeutic activities (e.g. rubbing in, breathing therapy with tapping)	1	-
	food exposure (e.g. cleaning vegetables, food portioning)	-	2
	unspecified / other (e.g. assistance in endoscopy, laboratory work, podological treatments, activities with wet work)	4	4

COT = cotton; SYM = Sympatex

Table 5: Overview of the ratings of the tested glove combinations including glove liners made of cotton or Sympatex and previously used gloves without glove liners.

Group / comparison	Sympatex cohort (SYM)			Cotton cohort (COT)			SYM vs. COT
Statement	PUG M [±SD; n]	SYM M [±SD; n]	SYM vs. PUG (t-test for paired samples) <i>P</i> [t; df; <i>d_z</i>]	PUG M [±SD; n]	COT M [±SD; n]	COT vs. PUG (t-test for paired samples) <i>P</i> [t; df; <i>d_z</i>]	SYM vs. COT (t-test for unpaired samples) <i>P</i> [t; df; <i>d</i>]
<i>The climate under the gloves is pleasant.</i>	3.7 [±0.91; 36]	1.8 [±1.77; 65]	< 0.001 [-9.890; 35; -1.648]	4.0 [±0.95; 42]	2.0 [±0.93; 55]	< 0.001 [-10.191; 41; -1.573]	.233 [-1.199; 118; -0.220]
<i>My hands stay dry even when wearing gloves for a long time.</i>	4.4 [±0.83; 36]	2.0 [±1.11; 65]	< 0.001 [-11.821; 35; -1.970]	4.7 [±0.61; 42]	2.7 [±1.29; 55]	< 0.001 [-11.758; 41; -1.814]	.006 [-2.772; 118; -0.508]
<i>Movements can be executed purposefully with the gloves.</i>	1.9 [±1.16; 36]	1.9 [±0.88; 65]	.646 [-0.463; 35; -0.077]	1.7 [±1.01; 42]	2.1 [±1.00; 55]	.105 [1.655; 41; 0.255]	.125 [-1.546; 118; -0.283]
<i>The gloves are easy to wear in everyday working life.</i>	2.5 [±1.13; 36]	2.0 [±0.94; 65]	.045 [-2.082; 35; -0.347]	2.5 [±1.35; 42]	1.9 [±0.97; 54]	.006 [-2.883; 41; -0.445]	.612 [0.509; 117; 0.094]
<i>The material feels pleasant on the skin.</i>	3.3 [±1.09; 35]	1.8 [±0.82; 64]	< 0.001 [-5.887; 34; -0.995]	3.7 [±1.03; 42]	1.5 [±0.77; 55]	< 0.001 [-10.917; 41; -1.685]	.060 [1.900; 117; 0.349]
<i>The material gives a comfortable wearing experience.</i>	2.6 [±0.91; 35]	2.6 [±1.27; 65]	1.000 [0.000; 34; 0.000]	2.9 [±1.31; 40]	1.8 [±0.82; 55]	< 0.001 [-4.724; 39; -0.747]	< 0.001 [4.431; 110.452; 0.784]
<i>Under the gloves my skin feels moist.</i>	1.7 [±0.86; 36]	3.7 [±1.11; 65]	< 0.001 [9.238; 35; 1.540]	1.6 [±0.92; 42]	3.4 [±1.15; 55]	< 0.001 [9.279; 41; 1.432]	.121 [1.563; 118; 0.286]
<i>My skin feels uncomfortably warm under the gloves.</i>	2.3 [±1.11; 36]	4.0 [±1.14; 65]	< 0.001 [6.307; 35; 1.051]	2.5 [±1.21; 42]	3.6 [±1.13; 55]	< 0.001 [5.636; 41; 0.870]	.096 [1.676; 118; 0.307]
<i>The gloves impair the mobility of my hand / fingers.</i>	4.1 [±1.11; 36]	4.0 [±0.95; 65]	.513 [-0.661; 35; -0.110]	4.3 [±0.81; 42]	3.4 [±1.06; 55]	< 0.001 [-4.163; 41; -0.642]	.001 [3.258; 118; 0.597]
<i>The gloves strongly affect my sensitivity.</i>	3.8 [±1.13; 36]	3.7 [±1.07; 65]	.535 [-0.627; 35; -0.104]	3.9 [±1.20; 42]	3.1 [±1.10; 55]	< 0.001 [-3.636; 41; -0.561]	.003 [3.031; 118; 0.555]
<i>The look of the gloves bothers me.</i>	4.4 [±0.95; 35]	4.0 [±1.26; 64]	.026 [-2.333; 33; -0.400]	4.5 [±0.86; 42]	4.7 [±0.64; 55]	.225 [1.232; 41; 0.190]	< 0.001 [-3.639; 96.751; -0.640]

COT = cotton; SYM = Sympatex; PUG = previously used gloves without glove liners; M = mean value; n = absolute number; df = degrees of freedom t = t-value; SD = standard deviation; d = Cohen's d (unpaired t-test); *d_z* = Cohen's *d_z* (paired t-test); 5-point Likert scale for agreement: 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, 5 = strongly disagree.; Significant results are in bold.

Table 6: Comparison of the ratings of the tested glove combinations

Group / comparison	Sympatex cohort (SYM)			Cotton cohort (COT)			SYM vs. COT
Category	PUG M [±SD; n]	SYM M [±SD; n]	SYM vs. PUG (t-test for paired samples) <i>P</i> [t; df; <i>d_z</i>]	PUG M [±SD; n]	COT M [±SD; n]	COT vs. PUG (t-test for paired samples) <i>P</i> [t; df; <i>d_z</i>]	SYM vs. COT (t-test for unpaired samples) <i>P</i> [t; df; <i>d</i>]
<i>fit / fitting</i>	2.0 [±0.86; 35]	2.6 [±1.10; 65]	.016 [2.536; 34; 0.429]	2.0 [±0.92; 40]	2.0 [±0.79; 54]	.878 [0.154; 39; 0.024]	.001 [3.531; 114.749; 0.631]
<i>wearing comfort</i>	2.8 [±1.29; 35]	2.3 [±1.00; 65]	.053 [-2.007; 34; -0.339]	3.2 [±1.27; 40]	2.0 [±0.70; 54]	< 0.001 [-4.539; 39; -0.718]	.151 [1.446; 114.263; 0.258]
<i>mobility / flexibility</i>	2.0 [±1.06; 35]	2.1 [±1.01; 62]	.797 [-0.259; 32; -0.045]	1.9 [±1.08; 40]	2.5 [±0.82; 54]	.006 [2.890; 39; 0.457]	.022 [-2.322; 114; -0.432]
<i>tactility / tactile sensitivity</i>	2.2 [±1.03; 35]	2.3 [±0.92; 65]	.905 [-0.120; 34; -0.020]	2.0 [±1.15; 40]	3.0 [±1.17; 54]	< 0.001 [4.805; 39; 0.760]	< 0.001 [-3.938; 117; -0.725]
<i>donning and dotting</i>	2.5 [±1.17; 35]	3.4 [±1.29; 65]	.008 [2.814; 34; 0.476]	2.3 [±1.07; 39]	2.0 [±0.97; 54]	.347 [-0.953; 38; -0.153]	< 0.001 [6.800; 115.977; 1.220]
<i>perspiration / sweating</i>	4.6 [±1.08; 36]	2.0 [±1.17; 65]	< 0.001 [-10.158; 35; -1.693]	4.8 [±0.94; 40]	2.3 [1.09; 53]	< 0.001 [-12.078; 39; -1.910]	.148 [-1.458; 116; -0.270]
<i>suitability for everyday use</i>	2.8 [±1.21; 35]	2.6 [±1.12; 65]	.606 [-0.521; 34; -0.088]	2.9 [±1.29; 40]	2.4 [±1.12; 54]	.005 [-2.941; 39; -0.465]	.384 [0.874; 117; 0.161]
<i>appearance / look</i>	2.1 [±0.90; 34]	2.5 [±1.10; 64]	.102 [1.681; 33; 0.288]	2.1 [±0.89; 39]	2.1 [±0.79; 53]	.700 [-0.388; 38; -0.062]	.016 [2.439; 113.079; 0.440]
<i>overall / final evaluation combination</i>	not asked	2.3 [±0.84; 65]	not required	not asked	2.3 [±0.82; 54]	not required	.899 [-0.127; 117; -0.023]

COT = cotton; SYM = Sympatex; PUG = previously used gloves; M = mean value; n = absolute number; df = degrees of freedom t = t-value; SD = standard deviation; d = Cohen's d (unpaired t-test); *d_z* = Cohen's *d_z* (paired t-test); Scale based on the German school grades system consisting of six numerical grades 1: very good, 2: good, 3: satisfactory, 4: sufficient, 5: poor, 6: very poor.; Significant results are in bold.

Figure legends

Figure 1: Semipermeable Sympatex glove liner (a) and semipermeable Sympatex glove liner with occlusive protective gloves (b/c) (© iDerm Osnabrück)

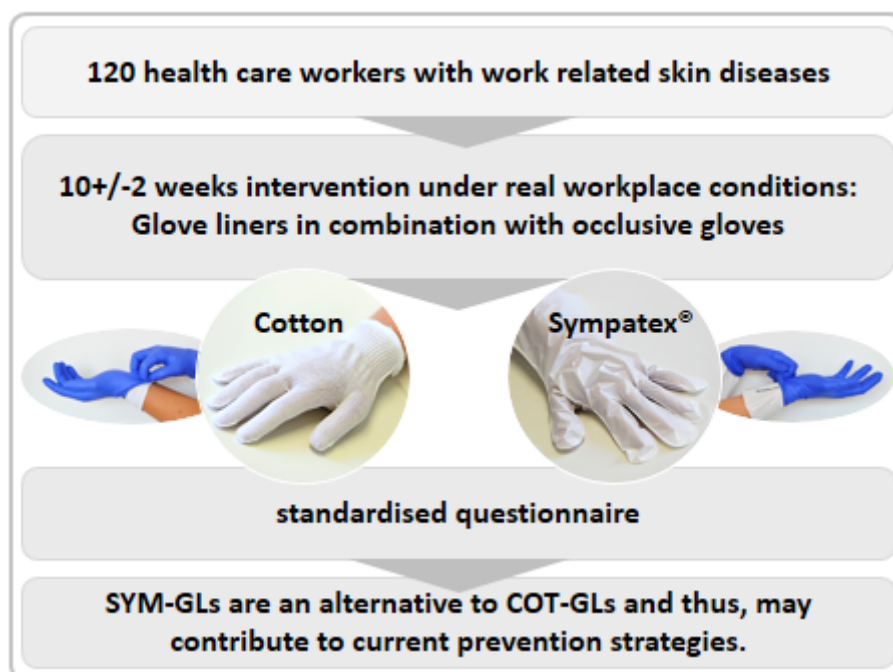
Figure 2: Cotton glove liner (a) and cotton glove liner with occlusive protective gloves (b, c; only for illustration purposes, the cuffs of the cotton gloves in b and c are longer than those of the occlusive protective gloves which will be avoided in daily professional practice). (© iDerm Osnabrück)



COD_13929_Figure_1.tiff.tif



COD_13929_Figure_2.tiff.tif



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