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Technical note: Influence of the drying position and time on the persistence of gunshot residues on fabrics

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ABSTRACT

The influence of the drying position and time on the persistence of gunshot residues (GSR) on fabrics was investigated. Powder tattooing from a 40 cm shooting distance on targeted fabrics were slightly wetted using a spray and dried for 3 h or 48 h in horizontal or vertical positions. The GSR particles were visualised using IR fluorescence with a Video Spectral Comparator (VSC) and automatically counted with a software before the wetting and after the drying stages. While a significant rate of GSR particles (up to 22%) were lost, it was mainly due to the wetting procedure rather than the drying stage. No statistically significant difference was observed between the drying positions, indicating that both drying positions can be used in practice to dry slightly wet fabrics. The drying time had no influence on the loss, and the GSR distribution was not significantly influenced by either factor (i.e., time and position).

1. Introduction

Gunshot residues (GSR) are produced when a firearm is discharged. The produced particles and compounds transfer on the surrounding surfaces, including the skin, hair, and clothing of the shooter, bystander (s), and target(s) [1–4]. The presence and distribution of GSR on the scene of investigation and persons of interest (POI) contribute to the reconstruction of firearm events. Thus, when such an incident occurs, the clothing of the different POI in an investigation are collected and seized for further examination. If the seized fabrics are damped or soaked with blood or other liquids (e.g., water) [5–7], they may need to be dried to avoid moulding during storage and soiling/contamination of the analysis material during the examination.

Even though the need for drying is often encountered in forensic cases, little to no research is available on how to proceed to avoid the loss or displacement of GSR on the clothing. This paper first aimed to survey how garments are dried in forensic laboratories. In a second stage, the influence of the drying position (i.e., horizontal or vertical) on the quantity and distribution of recovered GSR was investigated.

2. Material and methods

2.1. Survey

A survey in 18 forensic services[1] was carried out to find out the current practice for the drying of clothing that may retain GSR. The survey addressed the drying position, the use of drying facilitator (e.g., desiccator or airflow), and how contaminations between items were avoided. The detailed questionnaire can be found in the supporting information (it was translated into German, French, and English). The responses from the services have been anonymised, aggregated, and analysed to assess current practices.

2.2. Specimens

White, woven tissue (100% cotton, IKEA) was cut in samples of 30 × 30 cm^2. They were fixed vertically on a target and a shot at a 40 cm distance (muzzle to target) with a Sig Sauer P228 pistol (9 × 19 mm Parabellum calibre) was fired at the samples (see Fig. 1). Heavy-metal free Swiss Army ammunition of 9 × 19 mm Parabellum calibre from

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[1] Four laboratories from the European Network of Forensic Science Institutes, as well as 14 Swiss Regional Police services.

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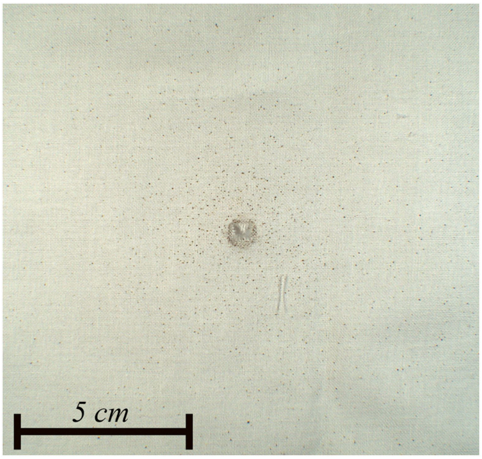

Fig. 1. Example of visible bullet hole and the bullet wipe in the centre, as well as GSR particles (mostly powder tattooing), on a fabric specimen, collected after a shot at 40 cm distance with a Sig Sauer P228 pistol.

the same batch were used (Pistolenpatrone 14, Manufacturer Thun). Before the experiments, the firearm was completely dismantled, cleaned, and lubricated with WD-40®. Initially, 10 shots were also fired with the selected ammunition to avoid memory effects. During the shooting experiment, the indoor shooting range ventilation was switched off. After every shot, the ventilation was switched on again for 10 min. After discharge, the shot fabrics were packed unfolded and horizontally in carton boxes, transported to a separate room, and stored until further analyses.

2.3. Instrumental method

GSR on specimens were visualised using IR fluorescence with a Video Spectral Comparator (VSC) 8000 instrument from Foster & Freeman. Specimens were illuminated using wavelengths at 545–674 nm and observed at 780 nm [7–9]. GSR particles (mostly powder tattooing) appeared white on a dark background (see Fig. 2). Standardised pictures were taken with the VSC placing the bullet hole in the middle of the field of observation. Photographs were taken in black-and-white, with an illumination time of 999 ms, aperture at 70%, zoom 2.11 x, and saved as TIFF files (resolution of 300 dpi). The focus was adjusted for all specimens in white light. A filter paper was placed under the specimens and was checked for contaminations before each new specimen. No cross-contaminations were observed using this procedure.

The number of particles was automatically and objectively counted using Adobe Photoshop® version 21.1.2. Particles were selected by selecting areas with "highlights" levels 214–255. Moreover, manual verification and modification of the selection was carried out for each specimen to avoid selection errors; for example, fluorescent fibres or other contaminations were manually deselected.

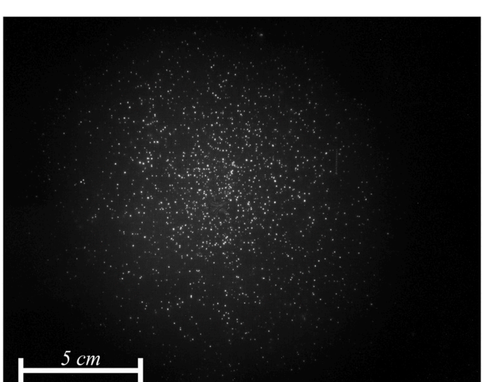

Fig. 2. Example of IR fluorescent GSR particles observed on a white cotton fabric using the VSC (excitation wavelength range at 545–674 nm, observation at 780 nm).

2.4. Drying experiments

Each specimen was wetted with 24.5 mL of water using a 0.5 L plastic spray (bought at Migros, Switzerland) and dried for 3 h or 48 h in a separate room. 24 specimens were prepared per timeframe for a total of 48 fabrics. Half of the specimens were laid on brown packing paper, the other half were hung on clothing lines with plastic clothespins in the same room (without ventilation and air conditioning). During the experiments, the average room temperature was 22.3 ± 0.6 °C and the average relative humidity was 32.8 ± 4.2%. Blank fabrics were placed between the laid or hanged specimens and analysed using the described VSC method. No contamination was observed (i.e., no GSR particle was detected on the blank fabrics using the VSC).

The specimens were photographed before wetting the specimens, and after wetting and drying (i.e., 2 images per specimen). To avoid humidity in the VSC instrument, it was not possible to take a picture of the wetted fabrics before drying. Unfortunately, an inadequate focus adjustment of the instrument after a change on the observation filters resulted in lower quality pictures that did not allow a reliable particle count for five specimens. Thus, results were obtained for 43 specimens (see Table 1).

2.5. Data treatment

The percentage of GSR particle loss was calculated for each specimen between the number of particles before wetting and after drying. These obtained data were tested for normality with the Shapiro-Wilks test at a significance level of 95%. As the data followed a normal distribution, a one-sided paired *t*-test at a significance level of 95% was used to evaluate if GSR particles were lost due to the wetting and drying process. A two-sided, unpaired *t*-test was used to evaluate if horizontal or vertical drying had a significant influence on the loss of GSR particles. The same test was used to investigate if the loss varied between 3 h and 48 h drying time.

3. Results and discussion

3.1. Survey

Fourteen Forensic Services of Regional Police in Switzerland as well as four European Forensic Institutes answered a survey about their drying protocols for fabrics susceptible to carry GSR. The forensic laboratories reported the use of varying drying protocols, often dependent on the available infrastructure. About half of the participants stated that clothing was dried exclusively or mostly vertically in their laboratory (10 out of 18 forensic services). Four services reported that they dried clothing only horizontally, and four reported the selection of one orientation depending on the circumstances of the case in question (see Fig. 3 – Left).

About a third of the responders reported the use of drying cabinets for the drying of clothing in a forensic context (Fig. 3 – Right). These cabinets were not specifically designed for the preservation of GSR and

Table 1
The specimens (n = 43) were sprayed with 24.5 mL of water and dried in a dedicated room either horizontally or vertically.

Drying time	# of specimens for which results were obtained	
	Horizontal drying	Vertical drying
3 h	11	10
48 h	10	12

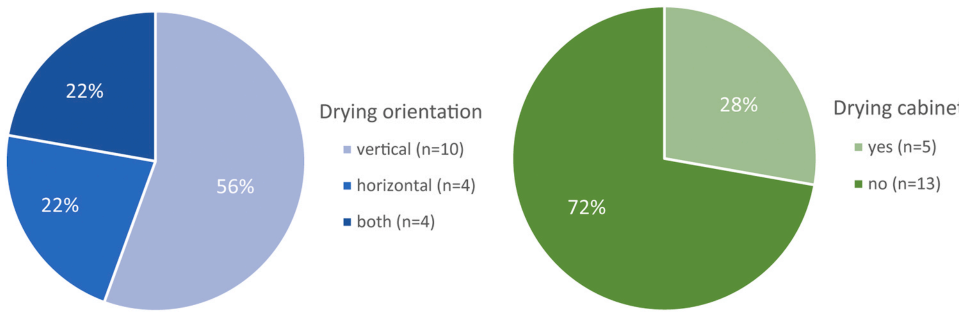

Fig. 3. Results of the survey for drying orientation (left) and use of drying cabinet (right).

operate with an airflow. They either allow only vertical drying or have different sections for horizontal and vertical drying. No test was carried out to study the risks of loss and contaminations during the use of drying cabinets, but special care was usually reported to clean the drying areas and discard the used material. The garments of potential victims and perpetrators, as well as different cases, were reported to be spatially separated (e.g., in separate rooms or drying cabinets*)*.

3.2. Wetting and drying experiments

The repeatability of the examination method was evaluated by replicating the IR photography and particle calculation 21 times from the same fabric (at 2 min intervals without displacing the specimen to avoid loss due to manipulation). A relative standard deviation (RSD) of 6% was obtained. A difference up to 99 particles (18%) between two replicates was obtained with a maximal value of 620 and a minimal value of 521 particles counted on the specimen. The images taken by the instrument lead to a slight decrease in the particle count over 40 min (see supporting information SI-1). This was due to a loss of intensity of the luminescence measurement light that was only noticed after the experiments were completed when treating the collected data. However, as replicates were always analysed in the same sequence and over the same time span, the instrumental induced variation was considered acceptable. The maximal difference in particle count between two consecutive measurements was 21 and the standard deviation over 40 min was 33 particles. In the future, the use of VSC to measure automatically GSR particles should be controlled over time to avoid larger instrumental errors (for example using a control sample).

On average for a total of 43 fabrics, 76 ± 41 particles were lost after the wetting and drying processes (see Table 2 and Fig. 4). This represented on average a loss of 9 ± 5% of the particles with a maximum loss of 22% (n = 205 particles, see SI-2). Three specimens led to no loss as 0, 7, and 14 additional particles were counted (48 h, horizontal drying). The additional particles can be explained by the experimental error of the instrument and the automatic particle counting method. No contamination was observed on the blank fabrics placed between the specimens.

It is interesting to note that over the 43 fabrics an average of 824 ± 123 particles was observed. This reflects the natural variation from one discharge to another using the same firearm, and ammunition from

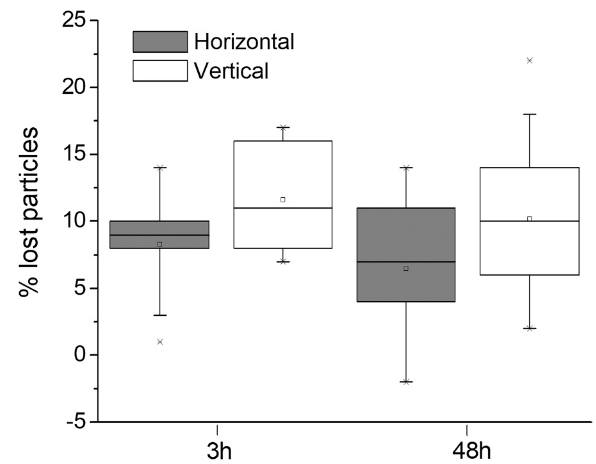

Fig. 4. Percentage of lost particles on the fabrics after 3 h and 48 h horizontal (grey boxplots) and vertical (white boxplots) drying.

the same batch, as well as the experimental error of the instrument and the automatic particle counting method. The number of particles detected ranged from 600 to 1141 (see SI-2). The observed loss of particles was statistically significant for all drying times and positions (see Table 2). A preliminary experiment indicated that loss mainly resulted from the wetting step (using a spray) rather than the drying stage (see SI-3).

The number of lost particles was on average slightly higher for vertical drying compared to horizontal drying, both for the 3 h and 48 h drying experiments (see Fig. 4). However, the difference represented only 3–4% of the total initial number of particles (which is below the error of measurement). Statistical tests confirmed that the difference was not significant between the two positions (see Table 3). The drying time (3 h vs 48 h) did not significantly influence the loss either (see Table 3).

Displacement of particles was also studied to evaluate if particles from the upper part of the fabric were displaced to the lowest part. The fabrics were divided in two and the number of particles above and below were counted (see Fig. 5 and SI-4). No statistically significant difference

Table 2
Average and standard deviation of lost particles counted on the specimens depending on drying time and position. *P*-values obtained when testing if wetting and drying fabrics induced a loss of GSR particles are indicated in the last column. Statistically significative percentage loss is indicated in grey (*p*-value threshold < 0.05).

		# Before	# After	# Loss	% Loss	*P*-value
3h	Horizontal (n=11)	817 ± 117	750 ± 110	67 ± 32	8 ± 4	1.75e-05
	Vertical (n=10)	807 ± 121	717 ± 128	91 ± 24	12 ± 4	4.01e-07
48h	Horizontal (n=11)	811 ± 142	753 ± 114	58 ± 48	7 ± 5	2.10e-03
	Vertical (n=10)	856 ± 121	767 ± 96	90 ± 61	10 ± 6	1.84e-04

Table 3
Two-sided *t*-test to evaluate the influence of the drying position and time on the loss of particles. Loss is statistically significative for *p*-value under 0.05 (none here).

Compared dataset	Dataset	*P*-value
Horizontal vs. Vertical	3 h	0.0573
	48 h	0.1741
3 h vs. 48 h	Horizontal	0.4217
	Vertical	0.5446

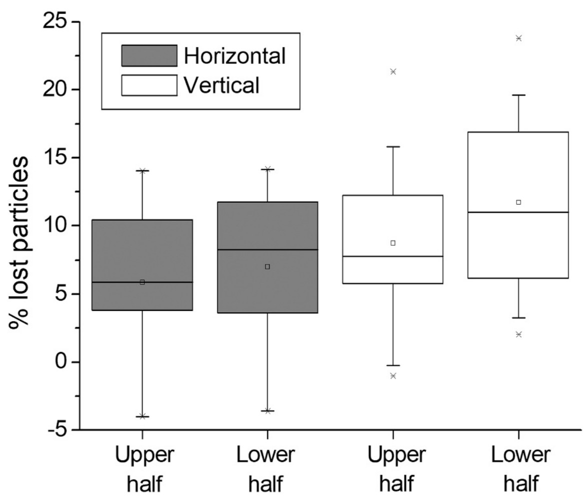

Fig. 5. Percentages of lost particles on the upper and the lower part of the fabrics for horizontal (grey boxplots) and vertical drying orientations (white boxplot) for the 48 h experiments.

was observed (p-value > 0.05), indicating that drying will not significantly influence the displacement of particles.

Each manipulation can lead to loss of particles. The particle less attached to the fabric would be lost first, for example when the fabrics were taken down from the wall or wetted (see SI-3). However, in practice forensic scientists will generally be able to measure GSR on fabrics only after they were wetted, seized, and dried. Obtained results indicated that the drying procedures used by forensic laboratories to dry and store slightly wetted fabrics were appropriate, at least when the specimens were examined for large quantities of particles (e.g. estimation of the shooting distance from the particle distribution). Further experiments would be needed to better understand the loss before the garments are brought to the laboratory. Different type of fabrics should also be tested as it can significantly influence the GSR pattern and persistence [10]. The way fabrics are wetted (e.g. spraying, bleeding, raining, immersing) as well as the quantities may also have a significant impact on the results [5–7,11].

4. Conclusion

After being shot at 40 cm with a 9 × 19 mm Parabellum pistol, fabrics were wetted and dried either horizontally or vertically. These manipulations (wetting and drying) lead to a loss of GSR particles. On average, 9 ± 5% of the particles were lost (with a maximum of 22%). There was no significant difference between the two drying positions (horizontal vs. vertical) and between drying times (3 h vs. 48 h). The observed loss did not lead to a displacement of the particles on the fabrics either. Thus, the determination of the shooting distance would not be hampered by the drying position or time. The optical observation using a VSC (IR fluorescence) led to a significant error over time. Thus, calibration to reduce the experimental error would be necessary for a reliable practical implementation of the instrument for GSR automatic count. In conclusion, this work indicated that the drying position had no significant influence on the GSR loss. Moreover, no contamination of blank fabrics was observed during the drying experiments. These results indicate that the procedures reported by forensic science services are adequate to dry slightly wet clothing contaminated with relatively high amount of GSR. However, further studies should evaluate if this is true for all type of fabrics, as well as for different wetting procedures and smaller amount of GSR (as expected with longer shooting distances).

CRediT authorship contribution statement

Julia Fischer: Conceptualization, Data Curation, Formal analysis, Visualization, Writing - Original Draft. **Virginie Redouté Minzière**: Conceptualization, Supervision, Resources, Writing - Review & Editing. **Denis Werner**: Conceptualization, Supervision, Formal analysis, Writing - Review & Editing. **Balthasar Jung:** Conceptualization, Supervision, Writing - Review & Editing. **Céline Weyermann**: Conceptualization, Supervision, Visualization, Writing - Original Draft.

Declaration of Competing Interest

None.

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