

ORIGINAL ARTICLE

Experimental evaluation of nickel and cobalt release from tools and self-reported prevalence of nickel and cobalt allergy in the German hairdressing trade

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Abstract

Background Nickel release from some metal tools in the hairdressing trade has been sporadically evidenced, whereas data about cobalt release from metal tools in the hairdressing trade are lacking.

Objectives To screen metal tools for nickel and cobalt release and to estimate the prevalence of nickel allergy and cobalt allergy in the German hairdressing trade.

Methods Four hundred seventy-five metal tools in the hairdressing trade were tested in three North German states with a nickel spot test for nickel release and with a cobalt spot test for cobalt release. Seventy hairdressers were surveyed with a standardized questionnaire to collect data about the tested metal tools as well as the prevalence of nickel allergy and cobalt allergy.

Results One hundred thirty-one of 475 metal tools (27.6%) – 60 of 60 hair clips (100%), five of five crochet hooks (100%), 24 of 40 tweezers (60.0%), 33 of 75 sectioning clips (44.0%), five of 32 straight razors (15.6%), and four of 45 tail combs (8.9%) – released nickel and 10 of 475 metal tools (2.1%) – three of 40 tweezers (7.5%), four of 60 hair clips (6.7%), one of 32 straight razors (3.1%), and two of 75 sectioning clips (2.7%) – released cobalt. Eight of 63 female hairdressers (12.7%) suffered from nickel allergy and two of 63 female hairdressers (3.2%) suffered from cobalt allergy.

Conclusions Metal tools in the German hairdressing trade – with which a prolonged skin contact is intended – release nickel and cobalt in allergologically relevant amounts and thus should be taken into account as occupational sources of exposure to nickel and cobalt.

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Conflicts of interest

None declared. Ms. Symanzik, Prof. Skudlik and Prof. John have nothing to disclose.

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Introduction

Nickel and cobalt rank amongst the most common contact allergens. According to current data of the Information Network of Departments of Dermatology (IVDK), the sensitization prevalence of nickel is 14.7% and the sensitization prevalence of cobalt is 5.2%.¹ The use of nickel in metal objects within the European Union (EU) is regulated by the Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation (REACH),² whereas no regulation regarding the utilization of cobalt in metal objects is in force. Metal objects with an intended prolonged skin contact must not release nickel above the threshold value of $>0.5 \mu\text{g}/\text{cm}^2/\text{week}$.² A prolonged skin contact is defined by the

European Chemicals Agency (ECHA) as skin contact with nickel of more than (i) 10 min on three or more occasions within 2 weeks or (ii) 30 min on one or more occasions within 2 weeks.³

Various studies have shown that a nickel release as well as a cobalt release from metal tools is existent in diverse occupational areas within the EU (Table 1).^{4–9} Two comparable studies have already been conducted in the hairdressing trade.^{4,9} A Danish study showed that eight of 213 (3.7%) metal tools released nickel.⁵ In Germany, a nickel release was detected in 21 of 229 (9.2%) metal tools.⁹ At present, no comparable studies regarding a cobalt release from metal tools in the hairdressing trade are available.

Table 1 Summary of positive nickel and cobalt test results of studies in which occupationally used metal tools were tested for nickel release in the European Union (EU)

Study	Occupational area	Nickel positive		Cobalt positive	
		%	<i>n/n_{total}</i>	%	<i>n/n_{total}</i>
Thyssen <i>et al.</i> (2009) ⁴	Hairdressing trade†	3.7	8/213	N/T	N/T
Thyssen <i>et al.</i> (2010) ⁵	Various areas†	50.0	18/36	N/T	N/T
Kettelarj <i>et al.</i> (2014) ⁶	Healthcare industry	32.8	20/61	37.7	23/61
Kickinger-Lörsch <i>et al.</i> (2015) ⁷	Construction industry†	32.5	195/600	1.0	6/600
Ringborg <i>et al.</i> (2016) ⁸	Various areas†	53.8	35/65	N/T	N/T
Symanzik <i>et al.</i> (2019) ⁹	Hairdressing trade†	9.2	21/229	N/T	N/T
Present study	Hairdressing trade†	27.6	131/475	2.1	10/475

N/T, not tested.

†Scissors and crochet hooks. ‡Keys, watches, knitting needles, scissors and work tools. §Dental tools (drill bits, grinding discs, brushes, scissors, forceps, pliers, articulators, measuring tools and matrix band) and dental alloys. ¶Wrench keys, lathe tools, pliers, chisels, nuts, files, hammers, nails, screws, spatulas and saws. ††Utensils for needlework, painting and writing (thimbles, crochet hooks, knitting needles, needles, paintbrushes and pens). ‡‡Scissors, sectioning clips, hair rollers, tail combs, whisks, tweezers and hand showers; §§Scissors, sectioning clips, hair clips, hair rollers, tail combs, tweezers, straight razors, whisks, hand showers and crochet hooks.

The release of contact allergens from metal tools in the hairdressing trade poses a health threat to the workforce in terms of developing contact allergy and consequently allergic contact dermatitis. A decrease of the prevalence of nickel allergy in the EU has been observed after the REACH regulation has been implemented.^{10–14} Notwithstanding, it has also been pointed out that nickel allergy is still frequent and thus continuously poses a health risk within the EU – especially in the female population.¹³ Due to the fact that there are no regulations regarding the usage restrictions of cobalt, a change in the prevalence of cobalt allergy was not witnessed.¹⁴ Current data have shown that nickel and cobalt allergy is frequent in the professional group of hairdressers.^{15,16} Occupationally developed allergy presents a particular macrosocial problem as it may entail social consequences such as an occupational change or a premature exit from the labour market.¹⁷

The aim of the present study was to screen a wide spectrum of metal tools for nickel and cobalt release as well as to record the self-reported prevalence of nickel and cobalt allergy in the German hairdressing trade.

Materials and methods

Eighteen hair salons of different price segments – low ($n = 6$), medium ($n = 6$) and high ($n = 6$) – were visited in equal proportions in Lower Saxony, North Rhine-Westphalia and Schleswig-Holstein. The salons were chosen randomly according to their willingness to participate.

The commercially available test solutions Chemo Nickel Test, Chemotechnique Diagnostics, Vellinge, Sweden and Chemo Cobalt Test, Chemotechnique Diagnostics, Vellinge, Sweden, were used to test metal tools for nickel release and cobalt release. The Chemo Nickel Test – also called nickel spot test – is a dimethylglyoxime (DMG) test solution and contains the following ingredients: water, ethanol, ammonium hydroxide and

DMG (CAS no. 95-45-4). The Chemo Cobalt Test – also referred to as cobalt spot test – is a nitroso-r salt (disodium-1-nitroso-2-naphthol-3,6-disulphonate) test solution and contains the subsequently listed ingredients: water, sodium acetate, oxalic acid and nitroso-r salt (CAS no. 525-05-03). For the testing, ordinary white cotton swabs from pure cotton wool of the brand ebelin, dm-drogerie markt, Karlsruhe, Germany, were utilized.

The following metal tools – with which hairdressers may have prolonged skin contact according to the definition of the ECHA³ – were included in the study: scissors, sectioning clips, hair clips, hair rollers, tail combs, tweezers, straight razors, whisks, hand showers and crochet hooks. The testing areas were determined in advance to guarantee standardized testing (Fig. 1; Table S1). Depending on the metal tools, the size of the testing areas averaged 0.5 cm². To ensure that the test results were not flawed by an overlapping of the two different test solutions, a free space of at least 1.25 cm was left out between the testing areas for the nickel and cobalt spot test. A 2.0 cm long strip of Leukofix, BSN medical, Hamburg, Germany, with a default width of 1.25 cm was placed between the designated testing areas on scissors and sectioning clips due to the size of these metal tools and the areas in which a prolonged skin contact with these tools is given (Fig. 2). For all other tested tools, a larger distance than 1.25 cm was kept between the different testing areas.

The nickel and cobalt spot testing was conducted as subsequently outlined, following the recommendation for action of the manufacturer of the test solutions. Two drops (~ 50 µL) of the appropriate test solution were in each case applied on a new cotton swab. The cotton swab was then rubbed against the predetermined testing area for up to 60 s. If a relevant colour change was visible before the time elapsed, the testing was halted at this instant. A colour change of the previously clear nickel test solution to a reddish-pink marked a positive test reaction, and a negative test reaction was given when no colour change of the



Figure 1 Tested metal tools with marked testing areas: (a) scissors, (b) tail comb, (c) straight razor, (d) crochet hook, (e) tweezers, (f) sectioning clip, (g) hair clip, (h) hair roller, (i) whisk and (j) hand shower. The testing areas for the nickel spot test are marked with a cross (x) and the testing areas for the cobalt spot test are marked with a circle (o). Testing areas in which the nickel and cobalt spot tests were conducted at the analogous opposite side of the metal tool are marked with an asterisk (*).

test solution was visible.^{18,19} A positive test reaction of the cobalt test solution was indicated through a colour change of the previously yellow test solution to a reddish-brown, and a negative reaction was marked through no colour change of the yellow test solution.^{18,20,21} For both test solutions, inconclusive test reactions were marked by blue, green or black colour changes. For optimal colour recognition, the cotton swabs were placed in front of a white surface when evaluating the colour change. Testing was performed on the metal tools in their existing condition without any prior cleaning or manipulation. In order to verify the reproducibility of the test results, 48 of the previously tested

metal tools (10.1%) were randomly selected and retested after 2 weeks. The results were reproducible at 100%.

An employee survey was conducted using written standardized questionnaires. All hairdressers ($n = 70$) in the visited salons ($n = 18$) were asked to fill in the questionnaire. Data about the metal tools – the age, price and manufacturer of all metal tools as well as additionally the model of the scissors – and data about nickel and cobalt allergies in the hairdressing trade were collected. The hairdressers were asked whether they suffer from nickel allergy or cobalt allergy, how long the allergy persists, and whether the allergy was diagnosed by a dermatologist through

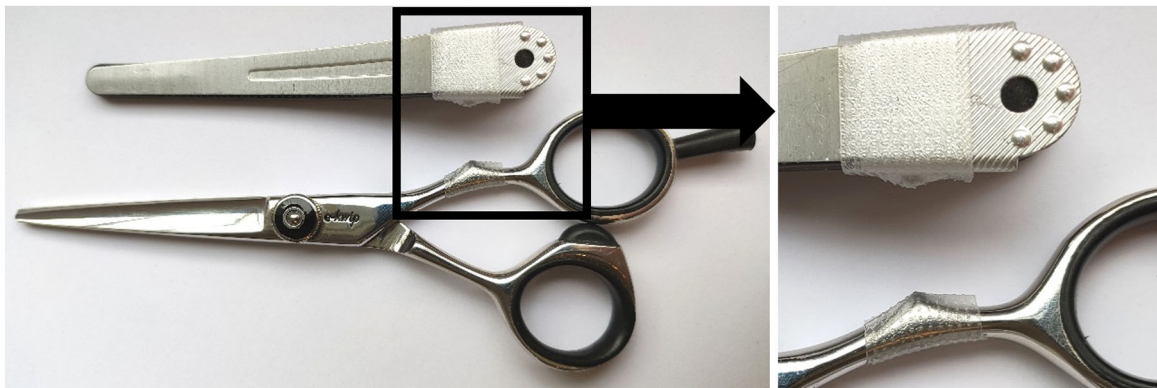


Figure 2 Attachment of a 2.0 cm long strip of Leukofix, BSN medical, Hamburg, Germany with a default width of 1.25 cm between the designated testing areas on scissors and sectioning clips in order to ensure a standardized minimum distance of 1.25 cm between the individual testing areas.

patch testing. Further, the age and the gender of the hairdressers were documented.

Results

Nickel and cobalt test results

In total, 475 metal tools – 116 scissors, 75 sectioning clips, 60 hair clips, 60 hair rollers, 45 tail combs, 40 tweezers, 32 straight razors, 22 whisks, 20 hand showers and five crochet hooks – were tested for nickel and cobalt release. The Chemo Nickel Test showed that 131 of 475 metal tools (27.6%) released nickel and the Chemo Cobalt Test showed that 10 of 475 metal tools (2.1%) released cobalt. Positive nickel and cobalt test results are summarized in Table 2. All cobalt-releasing metal tools simultaneously released nickel. Nickel-releasing metal tools were found in every visited hair salon regardless of the price segment and

the geographical location, whereas cobalt releasing metal tools were not detected in every visited hair salon, but in hair salons of every price segment and every geographical location.

All tested 116 scissors, 22 whisks and 20 hand showers showed negative nickel test results and all tested 60 hair rollers, 45 tail combs, 22 whisks, 20 hand showers and five crochet hooks showed negative cobalt test results. Eighteen inconclusive nickel test reactions – shown by 16 black (88.9%) and two blue (11.1%) colour changes of the test solution – were given in eight of 60 hair rollers (13.3%), two of 32 straight razors (6.2%), four of 75 sectioning clips (5.3%), two of 40 tweezers (5.0%) and two of 45 tail combs (4.4%). Twenty-six inconclusive cobalt test reactions – indicated by 12 blue (46.2%), nine black (34.6%) and five green (19.2%) colour changes of the test solution – were observed in 10 of 60 hair rollers (16.7%), two of 45 tail combs (14.4%), five of 40 tweezers (12.5%), two of 32 straight razors (8.7%), four of 75 sectioning clips (5.3%) and three of 116 scissors (2.6%).

The use of further metal tools – with which no prolonged skin contact is intended, as for instance measuring spoons for blonding powder and tube squeezers – as well as non-metallic tools with metal parts – with which a prolonged skin contact may be given, as for example bobby pin bracelets – was observed whilst the testing was conducted in the hair salons (Fig. 3).

Table 2 Positive nickel and cobalt test results of the tested metal tools in the present study

Metal tools	Nickel positive		Cobalt positive	
	%	n/n _{total}	%	n/n _{total}
Hair clips	100	60/60	6.7	4/60
Crochet hooks	100	5/5	0	0/5
Tweezers	60.0	24/40	7.5	3/40
Sectioning clips	44.0	33/75	2.7	2/75
Straight razors	15.6	5/32	3.1	1/32
Tail combs	8.9	4/45	0	0/45
All	27.6	131/475	2.1	10/475

Scissors, sectioning clips, hair clips, hair rollers, tail combs, tweezers, straight razors, whisks, hand showers and crochet hooks were tested for nickel and cobalt release. All tested 116 scissors, 22 whisks and 20 hand showers showed negative nickel test results and all tested 60 hair rollers, 45 tail combs, 22 whisks, 20 hand showers and five crochet hooks showed negative cobalt test results.

Results of the employee survey

The employee survey regarding data about the manufacturer, price, and age of nickel and cobalt releasing metal tools showed that nickel and cobalt release was found in metal tools of different manufacturers, ages and pricing. The numbers of manufacturers, price ranges and the age of the nickel and/or cobalt releasing metal tools are summarized in Table 3.

The survey regarding nickel and cobalt allergies diagnosed by patch testing involved 70 hairdressers – 63 women (90.0%) and



Figure 3 Additional metal tools and non-metallic tools with metallic parts used in the hairdressing trade: (a) bobby pin bracelet, (b) measuring spoons for blonding powder and (c) tube squeezer.

Table 3 Metal tools which were tested positive for nickel and/or cobalt release with the corresponding recorded parameters manufacturer, age and price

Metal tools	Nickel-releasing metal tools			Cobalt-releasing metal tools		
	No. of manufacturers	Price range (€)	Age span (years)	No. of manufacturers	Price/price range (€)	Age (years)
Hair clips	3	0.05–0.10	0.5–20	N/A	0.05	25
Crochet hooks	2	2.00–5.00	15–30	N	N	N
Tweezers	10	2.00–25.00	0.5–40	3	15.00–25.00	5
Sectioning clips	3	0.45–1.80	0.5–20	1	0.45	1
Straight razors	3	12.50–35.00	8–25	1	12.50	25
Tail combs	N/A	2.00–3.00	6–12	N	N	N

N, none; N/A, not available.

seven men (10.0%), aged 16–69 years (average of 43.6 ± 12.9). It showed that eight (11.4%) of 70 hairdressers, all female, suffered from nickel allergy for 18 ± 9.4 years and two

(2.9%) of them also had cobalt allergy for 15.5 ± 0.7 years (Table 4). Their age ranged from 19 to 51 years (average of 36.9 ± 12.4).

Table 4 Self-reported prevalence of nickel allergy and cobalt allergy amongst surveyed hairdressers within the present study conducted in the German hairdressing trade stratified by age group

Age group (years)	Nickel allergy		Cobalt allergy	
	%	n/n _{total}	%	n/n _{total}
16–33	4.8	2/42	0	0/42
34–51	31.6	6/19	10.5	2/19
52–69	0	0/9	0	0/9
All	11.4	8/70	2.9	2/70

Discussion

The nickel and cobalt spot testing evidenced that a considerable amount of metal tools in the German hairdressing trade release nickel and cobalt, whereby the nickel release probably might be exceeding legally binding limiting values. It has been proven in previous studies that the nickel spot test and the cobalt spot test are suitable for detecting a release of allergologically relevant amounts of nickel²² and cobalt,²¹ respectively. Compared to other studies conducted in the hairdressing trade,^{4,9} the nickel release from metal tools of 27.6% in the presented study is particularly high. This might be attributed to the extended range of tested metal tools in the present study. The cobalt release from metal tools of 2.1% is moderate in comparison with studies examining cobalt release from metal tools in other occupational fields.^{6,7} The results of the presented study may be considered relevant for the whole German hairdressing trade due to the fact that the tested metal tools are sold nationally and nickel as well as cobalt release was detected in salons of all price ranges and all included German states. Furthermore, the results may be transferable to diverse European countries as a proportion of the tested metal tools is also sold within other European countries.

The occurrence of inconclusive test results (18 inconclusive nickel test reactions and 26 inconclusive cobalt test reactions) – which indicate release of other metals than the targeted metals – was to be expected due to the fact that inconclusive test reactions of the nickel spot test^{6,8} and the cobalt spot test⁶ have been observed in previous studies. Inconclusive test reactions should neither be interpreted as negative⁶ nor positive reactions, as the accurate outcome remains unclear. Only a green colour change of a cobalt spot testing solution is documented as indicating iron release.²³

Hairdressers are exposed to a high occupational skin strain provoked by a considerable quantity of working in wet conditions²⁴ as well as skin contact to detergents²⁵ and salon chemicals. The penetration of allergens into the skin is enhanced by the emerging damage of the skin barrier homeostasis.²⁴ Preceding studies have shown that there is a relation between nickel and cobalt sensitization²⁶ and further that nickel has to be considered as an adjuvant in the process of cobalt sensitization.²⁷ Co-exposure to nickel and cobalt

should strictly be avoided²⁷ – along with a general preventive allergen avoidance²⁸ in sensitized patients – to prevent sensitization as well as elicitation of contact allergy. This may be relevant to other professional groups as well, since some metal tools as for example tweezers are also widely used by people working in the cosmetic industry.

The results of the employee survey point out that metal tools of different manufacturers, ages, and pricing release nickel and cobalt, even though information about these parameters could not unfaithfully be given by the hairdressers (Table). The age structure of the nickel-releasing metal tools is of particular interest. In the REACH Regulation, it is stated that nickel must not be used in metal objects ‘where these have a non-nickel coating unless such coating is sufficient to ensure that the rate of nickel release from those parts of such articles coming into direct and prolonged contact with the skin will not exceed 0.5 µg/cm²/week for a period of at least 2 years of normal use of the article’.² Metal tools in the present study which did not exceed this 2 year mark released nickel. This demonstrates that metal tools which are supposed to be manufactured according to current regulations might still be considered as sources of exposure to nickel.

In forthcoming studies, quantitative methods should be utilized in order to determine the precise amount of nickel^{6,29} and cobalt^{6,29–31} released from metal objects in the hairdressing trade. Correspondingly, nickel and cobalt could be verified on the skin of hairdressers with a range of qualitative and quantitative methods.^{20,32–36}

Regarding the self-reported prevalence of nickel allergy, it is particularly noteworthy that nickel allergy was most frequently reported amongst middle-aged hairdressers, but also in hairdressers of a young age. This stresses the fact that the execution of the REACH Regulation should strictly be observed in order to better protect the European population from nickel release of metal tools. Relating to the duration of the existence of documented nickel and cobalt allergy, it cannot be excluded that a proportion of hairdressers was sensitized (or boosted in case of a pre-existing sensitization) in the occupational setting through skin contact to nickel and cobalt releasing metal tools.

Summarizing, a nickel release of 27.6% and cobalt release of 2.1% were detected from a wide range of metal tools with which hairdressers may have daily prolonged skin contact in the hairdressing trade. Metal tools of various manufacturers as well as diverse prices and age ranges have to be taken into account as occupational sources of exposure to nickel and cobalt. Metal tools simultaneously releasing nickel and cobalt have to be considered particularly problematic as they present a major health risk in terms of developing nickel allergy and cobalt allergy. In addition to a strict control of compliance of the REACH Regulation, establishing threshold limit regulations regarding the use of cobalt in metal tools seems appropriate. Dermatologists as well as

occupational health physicians may arrange testing of occupationally used metal tools for nickel or cobalt release when confronted with suspected nickel or cobalt allergy in the occupational group of hairdressers.

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Author contributions

C. Symanzik, C. Skudlik and S. M. John developed the presented idea and designed the research study. C. Skudlik and S. M. John provided essential reagents. C. Symanzik performed the research. C. Symanzik, C. Skudlik and S. M. John analysed the data. C. Symanzik wrote the paper in consultation with C. Skudlik and S. M. John. C. Symanzik, C. Skudlik and S. M. John provided critical feedback and shaped the research, analysis, interpretation and the overall manuscript. C. Symanzik, C. Skudlik and S. M. John finally approved the manuscript and are accountable for all aspects of the work.

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Supporting information

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

Table S1. Tested metal tools along with corresponding testing areas for nickel and cobalt release.

Table 1. Tested metal tools along with corresponding testing areas for nickel and cobalt release

Metal tools	Testing areas for nickel release	Testing areas for cobalt release
Scissors	Upper scissor shank, finger rest of the index finger	Upper scissor shank, finger rest of the middle finger
Sectioning clips	Lower gripping surface, frontal contact area	Lower gripping surface, posterior contact area
Hair clips	Upper gripping surface	Lower gripping surface
Hair rollers	Right edge area	Left edge area
Tail combs	Upper tail area	Middle tail area
Tweezers	Upper gripping surface, finger rest of the thumb	Lower gripping area, finger rest of the index finger
Straight razors	Upper gripping surface, frontal contact area	Upper gripping surface, posterior contact area
Whisks	Middle gripping surface	Upper gripping surface
Hand showers	Upper gripping surface	Lower gripping surface
Crochet hooks	Upper handle area	Lower handle area