

Nickel and cobalt release from jewellery and metal clothing items in Korea

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Summary

Background. In Korea, the prevalence of nickel allergy has shown a sharply increasing trend. Cobalt contact allergy is often associated with concomitant reactions to nickel, and is more common in Korea than in western countries.

Objective. The aim of the present study was to investigate the prevalence of items that release nickel and cobalt on the Korean market.

Materials and methods. A total of 471 items that included 193 branded jewellery, 202 non-branded jewellery and 76 metal clothing items were sampled and studied with a dimethylglyoxime (DMG) test and a cobalt spot test to detect nickel and cobalt release, respectively.

Results. Nickel release was detected in 47.8% of the tested items. The positive rates in the DMG test were 12.4% for the branded jewellery, 70.8% for the non-branded jewellery, and 76.3% for the metal clothing items. Cobalt release was found in 6.2% of items. Among the types of jewellery, belts and hair pins showed higher positive rates in both the DMG test and the cobalt spot test.

Conclusion. Our study shows that the prevalence of items that release nickel or cobalt among jewellery and metal clothing items is high in Korea.

Key words: allergy; cobalt; cobalt spot test; contact dermatitis; dimethylglyoxime test; jewellery; nickel.

Nickel is the most common single substance causing contact allergy, which may develop following prolonged or repetitive skin contact with metal items that release nickel. Common items that often cause nickel contact dermatitis include jewellery, metal clothing items, and coins. In Europe, the EU Nickel Directive was enacted to limit the amount of nickel released to $< 0.5 \mu\text{g}/\text{cm}^2/\text{week}$ from certain products that come into direct and prolonged

contact with a consumer's skin (1). After this intervention came into full force in July 2001, the frequency of items that release nickel on the market and the prevalence of nickel allergy were reduced in Europe (2–8). In contrast, nickel sensitization is still increasing in Korea. There are twice as many persons with positive patch test results in Korea than in Europe and western countries (9–14). The main cause of the increase in nickel sensitization is thought to be an increased use of diverse jewellery and metallic accessories (5, 14). Another reason for the high prevalence of nickel sensitization in Korea is the lack of regulations regarding the release of nickel from metal products. An amendment that limits nickel release to $< 0.5 \mu\text{g}/\text{cm}^2/\text{week}$ from metal products that can come into direct contact with the skin was announced in Korea in April 2012, and it will come into effect in July 2013.

Cobalt is also a common cause of metal allergy, and concomitant nickel and cobalt sensitization is frequently

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observed. The prevalence of positive patch test reactions to cobalt is the third highest following nickel and thimerosal in Korea, and is higher than in western countries (10, 14).

This study was performed to identify the prevalence of jewellery and clothing metal items that release nickel on the Korean market, in an effort to provide basic data for the future determination of the efficacy of the nickel regulations. We also studied the prevalence of cobalt release from jewellery and clothing metal items. In addition, the utility of the dimethylglyoxime (DMG) spot test was validated by means of a quantitative EN1811 analysis.

Materials and Methods

Materials

From March 2012 to May 2012 in Seoul, Korea, jewellery and metal clothing items with different prices (1000–270 000 Korean won, which is approximately 1–200 US dollars) and various designs that could expose consumers to nickel and cobalt were selected. However, gold (content exceeding 58.5%) and silver jewellery items were excluded. A total of 471 products were included as test objects, consisting of 395 pieces of jewellery (193 pieces of branded jewellery and 202 pieces of non-branded jewellery) and 76 metal clothing items. The spots that could potentially come into direct contact with the skin during use by the customer were tested. For each object, more than one spot was tested for most of the products. In total, 861 spots from 471 products were tested (Table 1).

There were seven types of jewellery tested; these items included both Korean-branded and non-branded products. Brand-name products were genuine products that had the brand name of a company that was officially registered in Korea. A total of 193 products from 12 brands were obtained, either by donations from the corporation behind each brand or by purchase. Non-branded products were products with relatively low prices from unknown manufacturers with no brand name. A total of 202 non-branded products were purchased from handicraft shops, personal jewellery shops, or street vendors in typical commercial districts in Seoul, such as the markets around Ewha Womans University, Myeong-dong, Dongdaemun, and Namdaemun.

Metal clothing items included buttons, hooks, snaps, studs, zippers, and metal accessories for clothing. A total of 76 clothing items were collected.

Methods

DMG test. Solutions of DMG (1.0% in denatured ethanol) and ammonium hydroxide (9.7% in water) were used; two drops of each solution were placed on a white

Table 1. Types and numbers of tested jewellery and metal clothing items

	Type	No. of products (no. of spots)	
		Branded	Non-branded
Jewellery	Belt	8 (16)	13 (26)
	Bracelet	21 (48)	17 (29)
	Earring	96 (188)	102 (201)
	Finger ring	18 (19)	22 (27)
	Hair pin	9 (9)	19 (20)
	Necklace	32 (85)	21 (41)
	Watch	9 (25)	8 (17)
	Total	193 (390)	202 (361)
Metal clothing items	Button		29 (54)
	Hook		10 (10)
	Snap		7 (7)
	Stud		3 (5)
	Zipper		7 (14)
	Others ^a		20 (20)
	Total		76 (110)
Total number of products tested (number of spots)			471 (861)

^aVarious metal accessories for clothing (e.g. string decoration) were tested.

cotton-tipped stick, which was rubbed on the spot to be tested for 30 seconds. The colour of the cotton was then assessed against a white background. The results were recorded, and classified as negative (no colour) or as positive (pink or red colour) reactions. Doubtful reactions, defined by colour changes other than pink or red, were registered as negative reactions. The detection limit of the DMG test has been estimated to be close to 0.5 µg/cm²/week (15, 16).

The EN1811 method: quantitative test for nickel release. Ten DMG test-positive and 10 test-negative products were randomly selected, and quantitative nickel release tests with the EN1811:1998 method (17) were carried out. The products were immersed in artificial sweat, which consisted of deionized and aerated water containing the following: 0.5% sodium chloride, 0.1% lactic acid, and 0.1% urea. The pH was adjusted to 6.5 with ammonium hydroxide. The flasks were left untouched in an oven at 30°C for 1 week for nickel extraction. The surface area of products that would not come into direct contact with the skin were masked off with tape, so that only nickel release from the surface that could potentially be in direct and prolonged contact with the skin was measured. The amount of nickel ions released into the artificial sweat was quantified with inductively coupled plasma–optical emission spectrometry (ICP-OES)

(Optima 5300DV; Perkin Elmer, Waltham, MA, USA). The limit of detection was calculated as three standard deviations from three blanks for the ICP-OES analysis. The resulting amount of nickel was divided by the exposed surface area to determine the nickel release rate ($\mu\text{g}/\text{cm}^2/\text{week}$). The surface area of all products was calculated manually, with Vernier calipers. The measured nickel release rate was multiplied by an adjustment factor of 0.1 as part of the EN1811:1998 standard method, which accounts for any inaccuracy of the test. The limit of detection was $0.01 \mu\text{g}/\text{cm}^2/\text{week}$ after the EN1811:1998 adjustment factor was applied ($0.1 \mu\text{g}/\text{cm}^2/\text{week}$ without the adjustment factor).

Cobalt spot test. A cobalt spot test was performed at a site different from that of the DMG spot test. However, the cobalt spot test was performed prior to the DMG test, because a positive DMG reaction may stain the product with pink–red discolouration, which can lead to a false-positive result in the subsequent cobalt spot test. The cobalt test solution was prepared by mixing 0.1% oxalic acid, 0.02% disodium-1-nitroso-2-naphthol-3,6-disulfonate (nitroso R salt) and 5.0% sodium acetate in deionized water. One drop of the cobalt test solution, a clear yellow solution, was added to the tip of a white cotton stick, which was then rubbed against the test product for 20–30 seconds. A colour change from yellow to red indicated that cobalt ions were released to the extent that they would elicit a positive patch test reaction in cobalt-allergic patients, with an approximate detection limit of 8 ppm (18, 19). Doubtful reactions, defined by colour changes other than red, were registered as negative reactions.

Statistical analysis

A chi-square test and Fisher's exact test in SPSS™ (version 19.0) were used for the analyses: a p -value of < 0.05 was considered to be statistically significant for the comparisons. To examine the trend of nickel allergy in Korea, Korean epidemiological studies of contact dermatitis from 1983 to 2008 (9, 11–13) were analysed with a Cochran–Armitage trend test in SAS™ (version 9.1).

Results

DMG test

Among a total of 471 products, 225 (47.8%) were positive in the DMG test. The positive rates were 12.4% for branded jewellery, 70.8% for non-branded jewellery, and 76.3% for metal clothing items. Non-branded jewellery showed a significantly higher positive rate than branded products ($p < 0.001$) (Table 2). In a comparison

Table 2. Results of the dimethylglyoxime (DMG) test for jewellery

Type	No. of DMG test-positive products/no. of products tested (%)		
	Branded	Non-branded	Total
Belt	6/8 (75.0)	11/13 (84.6)	17/21 (81.0) ^a
Bracelet	0/21 (0.0)	12/17 (70.6) ^b	12/38 (31.6)
Earring	6/96 (6.3)	66/102 (64.7) ^b	72/198 (36.3)
Finger ring	1/18 (5.6)	13/22 (59.1) ^b	14/40 (35.0)
Hair pin	6/9 (66.7)	18/19 (94.7)	24/28 (85.7) ^a
Necklace	4/32 (12.5)	18/21 (85.7) ^b	22/53 (41.5)
Watch	1/9 (11.1)	5/8 (62.5) ^b	6/17 (35.3)
Total	24/193 (12.4)	143/202 (70.8) ^b	167/395 (42.3)

^aVersus other types of jewellery: $p < 0.05$.

^bVersus branded: $p < 0.05$.

of seven types of jewellery, belts (81.0%) and hair pins (85.7%) had higher positive rates overall ($p < 0.001$) (Table 2). When we looked at individual types of jewellery, bracelets, earrings, finger rings, necklaces and watches showed significantly lower positive rates in the branded category than in the non-branded category. However, belts and hair pins showed high positive rates even in the branded category (75.0% and 66.7%, respectively), and no significant differences between branded and non-branded categories were noted (Table 2). In addition, among non-branded jewellery, products purchased from street vendors (83.3%) showed a higher proportion of DMG test-positive items than products from handicraft shops (66.2%) and personal jewellery shops (51.0%) ($p = 0.011$).

Positive reactions from metal clothing items were observed for 76.3% of all products, ranging from 57.1% to 100%, depending on the type of item (Table 3).

The EN1811 method: quantitative nickel release test

The DMG test-positive products showed a wide range of nickel release (0.2 – $88.4 \mu\text{g}/\text{cm}^2/\text{week}$) (Table 4).

Table 3. Results of the dimethylglyoxime (DMG) test for metal clothing items

Type	No. of DMG test-positive products/no. of products tested (%)
Button	22/29 (75.9)
Hook	8/10 (80.0)
Snap	4/7 (57.1)
Stud	2/3 (66.7)
Zipper	7/7 (100.0)
Others ^a	15/20 (75.0)
Total	58/76 (76.3)

^aVarious metal accessories for clothing (e.g. string decoration) were tested.

Table 4. Results of the EN1811 analysis of 10 selected dimethylglyoxime (DMG) test-positive products and 10 selected DMG test-negative products

Item number	Measured nickel release rate ($\mu\text{g}/\text{cm}^2/\text{week}$)	Calculated nickel release rate ^a ($\mu\text{g}/\text{cm}^2/\text{week}$)
DMG-positive products		
1	884	88.4
2	253	25.3
3	160	16.0
4	40	4.0
5	197	19.7
6	78	7.8
7	118	11.8
8	2	0.2 ^b
9	2.6	2.6
10	7.4	7.4
DMG-negative products		
11	< 0.1	< 0.01
12	< 0.1	< 0.01
13	< 0.1	< 0.01
14	24	2.4 ^c
15	< 0.1	< 0.01
16	13	1.3 ^c
17	< 0.1	< 0.01
18	< 0.1	< 0.01
19	< 0.1	< 0.01
20	< 0.1	< 0.01

^aCalculated values are the EN1811 results that the 0.1 adjustment factor is multiplied to measured values.

^bThe result indicates a false-positive DMG reaction.

^cThe result indicates a false-negative DMG reaction.

In contrast, most of the DMG test-negative products released $< 0.01 \mu\text{g}/\text{cm}^2/\text{week}$ of nickel, except for two products (2.4 and $1.3 \mu\text{g}/\text{cm}^2/\text{week}$) (Table 4). Because the detection limit of the DMG test has been estimated to be $\sim 0.5 \mu\text{g}/\text{cm}^2/\text{week}$, a false-positive DMG reaction is defined as a positive DMG test reaction with nickel release of $< 0.5 \mu\text{g}/\text{cm}^2/\text{week}$, and a false-negative reaction is determined to have occurred when a product with a negative DMG reaction releases nickel at a rate of $> 0.5 \mu\text{g}/\text{cm}^2/\text{week}$. Accordingly, one false-positive reaction (10%) and two false-negative reactions (20%) in the DMG tests were identified in this study.

Cobalt spot test

Among 471 products, 29 (6.2%) were positive in the cobalt spot test, and these were all positive in the DMG test. The positive rates of the cobalt spot tests were 4.2% for the branded jewellery, 5.0% for the non-branded jewellery, and 14.5% for the metal clothing items. The detailed results of the cobalt spot tests for the jewellery are shown in Table 5. Among the types of jewellery items, belts (28.6%) and hair pins (14.3%) showed higher

Table 5. Results of the cobalt spot test for jewellery

Type	No. of cobalt test-positive products/no. of products tested (%)		
	Branded	Non-branded	Total
Belt	4/8 (50.0)	2/13 (15.4)	6/21 (28.6) ^a
Bracelet	0/21 (0.0)	1/17 (5.9)	1/38 (2.6)
Earring	0/96 (0.0)	2/102 (2.0)	2/198 (1.0)
Finger ring	0/18 (0.0)	1/22 (4.6)	1/40 (2.5)
Hair pin	4/9 (44.4)	0/19 (0.0) ^b	4/28 (14.3) ^a
Necklace	0/32 (0.0)	3/21 (14.3)	3/53 (5.7)
Watch	0/9 (0.0)	1/8 (12.5)	1/17 (5.9)
Total	8/193 (4.2)	10/202 (5.0)	18/395 (4.6)

^aVersus other types of jewellery: $p < 0.05$.

^bVersus branded: $p < 0.05$.

Table 6. Results of the cobalt spot test for metal clothing items

Type	No. of cobalt test-positive products/no. of products tested (%)
Button	3/29 (10.3)
Hook	0/10 (0.0)
Snap	0/7 (0.0)
Stud	0/3 (0.0)
Zipper	7/7 (100.0)
Others ^a	1/20 (5.0)
Total	11/76 (14.5)

^aVarious metal accessories for clothing (e.g. string decoration) were tested.

positive rates than other types of jewellery ($p < 0.001$). Remarkably, cobalt release was more frequently detected in branded belts and branded hair pins than in non-branded products, which was in direct contrast to the results for nickel.

The types of metal clothing item with positive reactions were buttons, zippers, and one metal clothing accessory item. In particular, all zippers were positive in the cobalt spot test (Table 6).

Discussion

Nickel is the most common contact allergen, with the prevalence of nickel allergy being 15–20% in patients with contact dermatitis in Europe and North America (20, 21). In Korea, the prevalence is reported to be much higher; 27.1–34.1% of patients with contact dermatitis showed positive reactions to nickel in a patch test (10–12, 14, 22). Moreover, the prevalence of nickel allergy has increased in Korea. A continuously increasing trend since 1983 was observed ($p < 0.0001$), with a dramatic increase since 2001 (Fig. 1), when we analysed the Korean literature from 1983 to 2008 (9, 11–13) by using a Cochran–Armitage trend test. Increases in the

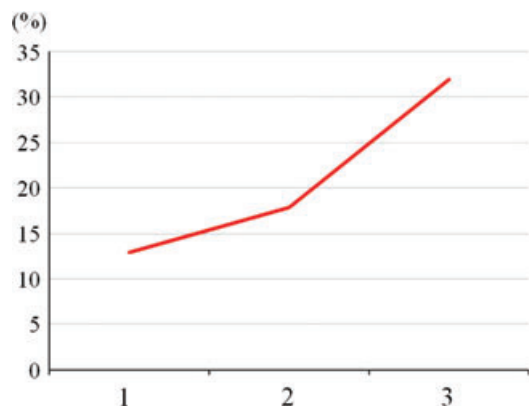


Fig. 1. Increasing trend for prevalence of positive patch test reactions for nickel in patients with contact dermatitis based on Korean Contact Dermatitis Research Group multicentre studies as analysed with the Cochran–Armitage trend test ($p < 0.0001$). [1, 1983–1985, $n = 937$ (9); 2, 1986–1993, $n = 2326$ (13); 3, 2000–2008, $n = 1204$ (11, 12)].

prevalence of nickel allergy have also been shown in other countries with no regulations pertaining to nickel release by metal products, such as the United States (23). The DMG test is not only an inexpensive and rapid method that detects nickel release, but is also a clinically relevant test for screening relatively safe products to protect nickel-sensitive customers (15, 16). Because the detection limit of the DMG test is $0.5 \mu\text{g}/\text{cm}^2/\text{week}$, and considering that nickel alloys with a nickel release rate below $0.5 \mu\text{g}/\text{cm}^2/\text{week}$ show weak reactivity in nickel-sensitive individuals, problems with nickel allergy can be minimized by using DMG test-negative products (16).

In this study, 47.8% of tested products showed positive DMG reactions, a markedly higher rate than those reported in previous studies (2, 3, 5, 6, 24–27). Although direct comparisons between studies are impossible, owing to differences in the composition and classification of test materials, the frequency of DMG test-positive jewellery has been suggested to be $\sim 10\%$ in regulated markets in Europe (2, 3, 6), and 25–30% in unregulated markets, such as the Swedish market before the Nickel Directive and in the markets in China, Thailand, and the United States (5, 25, 28). The frequency of DMG test-positive jewellery in Korea (42.3%) is notably higher than in other unregulated markets.

When jewellery was classified into branded and non-branded categories, the proportion of DMG test-positive items was significantly higher in the non-branded category than in the branded category (70.8% versus 12.4%). This finding is consistent with the results of previous surveys conducted in Europe, although each of the values is higher in Korea than in European countries

(2, 3, 25). In this study, the DMG test-positive rates of branded jewellery, except for belts and hair pins, was $\sim 10\%$ or lower, indicating that brand companies may have their own quality control system that limits nickel release, despite the fact that regulations pertaining to nickel release are not yet in effect in Korea. However, non-branded jewellery showed much higher DMG test-positive rates. Stratification by store category showed that the products from street vendors had a higher rate (83.3%) than the products from handicraft shops and personal jewellery shops. Thyssen et al. (27) reported a similar tendency in London, showing that DMG test-positive earrings were mainly purchased from street markets (38.7%) and from stores that seemed to have independent ownership (25%), and not from the stores of national or international accessory chains (0%), but the individual values were much lower than those in our study. Non-branded jewellery from street vendors is generally cheaper, and is mostly used by adolescents and young adults. Therefore, this may be one of the major sources of nickel sensitization in Korea.

Among the seven types of jewellery tested here, belts and hair pins showed high DMG test-positive rates (81.0% and 85.7%, respectively). Previous studies also showed that nickel release was frequent from belts and hair pins (3, 5, 6, 23, 24, 26, 29). The misconception that belts and hair pins do not directly come into contact with the skin may have led to the high prevalence of nickel-releasing belts and hair pins on the market. However, metallic belt buckles accounted for 38.4% of clinically relevant sources of exposure in Chinese nickel-allergic patients, emphasizing that belts are indeed a source of clinical problems (23). High frequencies of nickel-releasing belts were also found in Poland (56.2%) (24), China (60%), and the United States (55.7%) (23). Likewise, the highest DMG-test positive rate was found for hair slides (57%) among the types of jewellery on the Swedish market, even after implementation of the Nickel Directive (6). Hair pins are widely used by young children, who have thinner hair than adults. Therefore, they are also likely to come into frequent and direct contact with the skin (26). In an attempt to identify clinical sources of exposure in nickel-sensitized patients, belt buckles and hair pins were included in the relevant risk items, in addition to mobile phones, spectacle frames, watches, and keys (29). Whereas people are generally aware that metal earrings can be a source of nickel sensitization, they often do not regard other metal accessories, such as belt buckles and hair pins, as potential sources of sensitization.

Metal clothing items showed a high DMG test-positive rate of 76.3%. Similar results were reported from the Swedish and Dutch markets (2, 3, 5, 6), with the highest

rate being 96% (5). Metal buttons, studs, hooks, snaps, and zippers are widely used on most clothes, and can release nickel onto the skin of individuals. Therefore, the potential for nickel sensitization by these items also should not be overlooked.

When we validated the DMG test with the EN1811:1998 method, the false-positive and false-negative rates of the DMG tests were 10% and 20%, respectively. Previous studies reported false-positive rates of 3–30% and false-negative rates of 17–36% in the DMG test (30–32). The false-positive reaction in this study may have resulted from the presence of other metals that can confound the DMG results (e.g. iron). Another possible explanation for the false-positive reaction is the EN1811 adjustment factor. According to EN1811:1998 (17), the test method that is to be applied in Korea for the interpretation of compliance, the measured result is multiplied by an adjustment factor of 0.1. This adjustment factor was introduced to compensate for difficulties in the calculation of complicated area sizes, and for the lack of experience in applying the method for analysis of real objects. With this method, a product with a measured release rate as high as $5.0 \mu\text{g}/\text{cm}^2/\text{week}$ would be deemed to be compliant with the nickel regulation once the adjustment factor of 0.1 had been applied. Because the adjustment factor has a great impact on the interpretation of the results, a revised standard, EN1811:2011, in which the adjustment factor was replaced by an uncertainty of measurement was introduced to lower the compliance limit for nickel release. If EN1811:2011 is employed to validate the DMG test, the cases regarded as false-positive reactions may be reduced. Therefore, the Korean authorities should consider the use of the new EN1811:2011 method for the examination of compliance in their efforts to strengthen the level of protection in the future.

The false-negative reactions can be partly explained by a non-nickel coating that was not penetrated by the simple DMG challenge, but that corroded to release nickel ions when immersed in the artificial sweat during the EN1811 test (30). Therefore, when the simple DMG test is negative, pretreatment of the surface with artificial sweat and heat before the DMG test (prEN12471) is recommended to reduce false-negative results and to increase the sensitivity of the test. If false-negative results in the DMG test are taken into account, the current prevalence of DMG test-positive products may be higher in reality.

Because the amount of nickel penetrating per unit area of skin is one of the most important factors in nickel sensitization, regulations limiting the amount of nickel release are mandatory to reduce the rate of sensitization. In Korea, an amendment to limit nickel release to $\leq 0.5 \mu\text{g}/\text{cm}^2/\text{week}$ from metal products that

come into direct contact with the skin was announced in April 2012. Manufacturers of products intended to come into direct contact with the skin, such as rings, necklaces, bracelets, earrings, piercings, wrist watches, and hair ornaments, have to adhere to the tenets of this amendment. However, metal clothing items are not mentioned in this amendment. Because metal clothing items can be an important source of nickel release through direct contact with the skin, a clear statement is required. In Europe, the additional restriction of nickel release from items that are intended to be inserted into a pierced part of the human body to $< 0.2 \mu\text{g}/\text{cm}^2/\text{week}$ came into effect in 2005 (33), although such an amendment has not yet been incorporated in Korea.

Recent studies performed in Europe have shown that substantial amounts quantities of nickel-releasing products are being purchased, especially in street markets and independent shops, even after full enforcement of the Nickel Directive (3, 24, 27). Therefore, thorough surveillance and inspections of the market, especially for non-branded products from street vendors, are recommended for the proper implementation of the regulations. In addition, because the spontaneous participation of industry in limiting nickel release from jewellery and other metal products is not likely to become established, a national campaign to inform consumers, manufacturers, importers, and retailers, and necessary authoritative measures, may be warranted.

Despite the fact that the prevalence of nickel allergy decreased in European countries after the introduction of regulations on nickel, nickel allergy remains prevalent, and the proportion of positive nickel patch test reactions has remained stable at 10–20% in Europe (34–36). Nickel regulations can be regarded as an approach to reduce nickel allergy problems, but not as an attempt to abolish nickel allergy. A total ban on the use of nickel in consumer products would clearly reduce the problem more efficiently, but such action is impractical, owing to the many useful applications of nickel, given its low cost and good resistance to corrosion (37). Although customer items with a nickel release rate of $< 0.5 \mu\text{g}/\text{cm}^2/\text{week}$ are generally considered to be safe for most individuals who are allergic to nickel, a minority of them may still react below this limit and develop problems (38). In addition, occupational nickel exposure from metal items such as, tools, scissors, crochet hooks, coins, handles and keys also contributes to the prevalence of nickel allergy. Hence, the EU Nickel Directive has been revisited to enable further steps to be taken for the better protection of consumers and workers by dermatologists and regulators, as the current regulations are not sufficient to reduce the prevalence of nickel allergy further (37).

Cobalt is a silvery metal that is mostly used in the production of superalloys, corrosion-resistant alloys, prosthetics, magnets, colours, and jewellery. The concentration of cobalt necessary to elicit cobalt allergy in sensitized patients had been reported to be 50, 19 and 10 ppm, depending on the study (39–41). Because a cobalt spot test is able to identify cobalt ions in a cobalt nitrate standard solution at a concentration of ~8 ppm, it is considered to be a clinically relevant test that may serve well as a screening method for consumer products before use to protect cobalt-allergic individuals (19).

The prevalence of cobalt allergy in patients with contact dermatitis is reported to be 11.1–22.8% in Korea (10, 11, 22), which is much higher than the prevalence in western countries, at approximately 5–8% (20, 42, 43). In this study, the rate of cobalt release from jewellery and metal clothing items was remarkable, as 6.2% of items tested positive in the cobalt spot test. In previous studies, cobalt release was found for 1.1% of inexpensive jewellery items and in 0% of hand-held work tools in Denmark (18, 44), for 0.007% of inexpensive earrings from Thailand and China (45), and for 0.5–0.9% of belts in China and the United States (23). The use of cobalt in jewellery and metal products is suspected to be common on the Korean market and, consequently, frequent exposure to cobalt may account for the high prevalence of cobalt allergy in Korea. The abundance of both nickel-releasing items and cobalt-releasing items on the Korean market is probably one explanation for concomitant nickel and cobalt allergy. It is of interest that all products that tested positive in the cobalt spot test were also positive in the DMG test. Whereas items with a dark appearance released cobalt more frequently in previous reports (18, 23, 45), no

relationship with the colour of the products was observed in this study; only 10.3% of cobalt-releasing products had a dark appearance.

Among the types of jewellery, belts (28.6%) and hair pins (14.3%) showed statistically higher positive rates than other types of jewellery. In contrast to the case of nickel, cobalt release was more frequently detected for branded belts (50%) and branded hair pins (44.4%) than for their non-branded counterparts; this observation may be explained, to some degree, by the high cost of cobalt as compared with that of nickel. Positive cobalt spot test results were also observed with buttons and zippers. A further study of metal clothing items, including buttons and zippers, with stratification by price is necessary for a better understanding of the characteristics of cobalt-releasing items on the market. The detection of cobalt with an X-ray fluorescence spectrometer or structural characterization with a scanning electron microscope would also help in the future.

This study has some limitations, as follows. First, clothing, footwear products, and spectacles, all of which can also expose consumers to nickel or cobalt, were not included. In addition, stratification by jewellery price or by age group (i.e. children or adults) was not performed. However, this is the first large-scale market survey investigating the frequency of nickel and cobalt release from jewellery and metal clothing items in Korea. A large proportion of jewellery is estimated not to fulfil the requirements of the upcoming nickel regulations. We believe that this study provides basic data for future studies regarding the prevalence of items that release nickel and cobalt and for evaluations of the effects of the nickel regulations to be enforced in Korea.

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