

Assessment of Nickel and Cobalt Release From Jewelry From a Non–Nickel Directive Country

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Background: A directive restricting nickel release from jewelry and other skin-contact products has not been initiated in Thailand or in the United States. The prevalence of nickel and cobalt allergies is increasing, and the main cause of sensitization seems to be jewelry.

Objectives: We aimed to investigate nickel and cobalt release from jewelry available in Thai marketplaces and to study the factors associated with nickel and cobalt release.

Methods: Used costume jewelry items were collected from volunteers. They were tested with the dimethylglyoxime and cobalt tests.

Results: Five hundred fifty-one items, including belt buckles, bracelets, earrings, necklaces, rings, and watches, were tested; 216 (39.2%) gave positive dimethylglyoxime tests, and 206 (37.4%) gave positive cobalt tests. The factors that determined nickel or cobalt release were shopping location and jewelry price. Cobalt-containing jewelry could be identified by its dark color.

Conclusions: A large proportion of the jewelry sold in Thai markets release nickel or cobalt.

Nickel allergy is one of the commonest causes of allergic contact dermatitis worldwide.¹ The number of patients with nickel allergy is increasing rapidly because of exposure to nickel-releasing consumer items, mainly jewelry such as earrings, clasps, bracelets, necklaces, and watches.² Previous studies showed that increasing cutaneous exposure to nickel caused increases in nickel allergy in Europe, the United States, and Asia.^{3–5} The European Union (EU) Nickel Directive restricts the amount of nickel released from jewelry and other products that come into contact with the skin to a maximum of 0.5 g/cm² per week.⁶ This intervention has significantly decreased the number of products in Europe that release excessive amounts

of nickel⁷ and the prevalence of nickel allergy⁸; however, the directive has not been implemented in the United States and in most Asian countries.

Cobalt is the fourth most common allergen in Thailand, with a prevalence of 16.4%.⁹ However, in European countries, cobalt allergy affects approximately 3% to 6% of dermatitis patients undergoing routine patch testing.¹⁰ The amounts of nickel/cobalt in jewelry are important in causing nickel/cobalt allergies. The aims of this study were to explore the percentage of nickel-positive and cobalt-positive jewelry in Thai markets and to identify the factors related to nickel/cobalt allergies.

MATERIAL AND METHODS

Material Collection

The Siriraj Hospital institutional review board approved this study. The metal accessories in this study, including 28 belt buckles, 32 bracelets, 388 pairs of earrings, 60 necklaces, 22 rings, and 21 watches, had been used for various periods. Their owners allowed testing of these items for nickel and cobalt. The details of each piece of jewelry were recorded, including purchase location, price, color, and duration of use (Table 1).

Dimethylglyoxime Test

The dimethylglyoxime (DMG) test is a colorimetric method that is used as a screening test to detect nickel release that exceeds 0.5 g nickel/cm² per week.¹¹ Solutions of DMG (1.0% in denatured ethanol) and ammonium hydroxide in water were used. Two drops of each solution were placed on a white cotton-tipped

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Author Contributions: Drs Maneeprasopchoke, Kasemsarn, and Boonchai had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Dr Boonchai contributed to the study concept and design. Drs Maneeprasopchoke and Kasemsarn contributed to the acquisition of data. Drs Maneeprasopchoke and Kasemsarn contributed to the analysis and interpretation of data. Drs Maneeprasopchoke and Boonchai contributed to the drafting of the study. Drs Kasemsarn and Boonchai contributed to the critical revision of the study for important intellectual content. Dr Maneeprasopchoke and Suiwongsa contributed to the administrative, technical, and material support. Dr Boonchai contributed to the study supervision.

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TABLE 1. Results of DMG and Cobalt Tests on Metal Accessories

		Nickel Test, Positive (n = 216), n (%)	Cobalt Test, Positive (n = 206), n (%)
Metal accessories	Belt buckle (n = 28)	12 (42.9)	8 (28.6)
	Bracelet (n = 32)	9 (28.1)	15 (46.9)
	Earrings (n = 388)	165 (42.5)	148 (38.1)
	Necklace (n = 60)	22 (36.7)	25 (41.7)
	Ring (n = 22)	7 (31.8)	7 (31.8)
	Watch (n = 21)	1 (4.8)	3 (14.3)
Source	Department store (n = 130)	26 (20) ^{a,b,c}	41 (31.5)
	Internet (n = 125)	49 (39.2) ^a	36 (28.8) ^f
	Market (n = 278)	130 (46.8) ^b	123 (44.2) ^f
	Unknown (n = 18)	11 (61.1) ^c	6 (33.3)
Price, US \$	<10 (n = 299)	137 (45.8) ^{d,e}	128 (42.8) ^g
	10–20 (n = 201)	70 (34.8) ^d	70 (34.8) ^h
	>20 (n = 51)	9 (17.6) ^e	8 (15.7) ^{g,h}
Duration of use, y	<1 (n = 177)	66 (37.3)	58 (32.8)
	1–5 (n = 348)	139 (39.9)	136 (39.1)
	>5 (n = 26)	11 (42.3)	12 (46.2)
Color	Brass (n = 28)	13 (46.4)	16 (57.1) ^{ij}
	Gold (n = 143)	55 (38.5)	52 (36.4) ⁱ
	Gray (n = 61)	26 (42.6)	42 (68.9) ^{ij}
	Pink gold (n = 34)	8 (23.5)	19 (55.9) ^{ij}
	Silver (n = 285)	114 (40)	77 (27) ^j

^{a–j}Statistical significance ($P < 0.05$) found for comparison of pairs indicated by same letter.

stick, which was firmly rubbed on the metal surface to be tested for up to 1 minute. The nickel releases were graded as positive (pink or red) or negative (no color) reaction. Duplicate tests were performed on items giving a doubtful reaction; if the second test was also doubtful, the reaction was registered as negative. We were unable to perform quantitative measurements using the EN 1811 reference method¹¹ or x-ray fluorescence spectroscopy.³ The color change results were compared visually with the results from commercial kits.

Cobalt Test

Cobalt tests were conducted to determine whether the items released cobalt. The test reagent was produced by the hospital pharmacy at Siriraj Hospital, which formulated based on previous reports.^{12,13} The pieces were soaked in the test reagent for 5 minutes. The cobalt test produces a red color if cobalt ions are present at greater than or equal to 8 ppm.¹³ Duplicate tests were also performed in the case of doubtful reactions.

Statistical Analysis

The data were analyzed using descriptive analysis. Fisher exact or χ^2 tests were compared using PASW Statistics 18.0 (IBM Corporation, New York, NY). The difference was considered significant for P values less than 0.05.

RESULTS

The features of all 551 tested items are shown in Table 1; 70.4% of them were earrings. The items were bought from several

sources, most of them (50.5%) from markets (serving middle-income and low-income groups and selling cheaper items), 23.6% from department stores (catering to high-income groups and providing more expensive branded jewelry), and 22.7% via the internet. The jewelry prices were recorded according to the time of purchase. Half of the jewelry items (54.2%) were inexpensive (<US \$10). The items had been used for various periods, but only a small number (4.7%) were older than 5 years. The jewelry color was assessed visually; most of the items (51.7%) were silvery.

Nickel Test Results

Among the 551 items, 216 pieces (39.2%) gave positive DMG tests (Fig. 1). Jewelry purchased from department stores had a lower proportion of nickel release than those from other sources ($P < 0.001$). The number of positive DMG tests was significantly higher for inexpensive jewelry than for expensive jewelry ($P < 0.001$), as shown in Table 1. The duration of use and jewelry color could not be used to predict differences among nickel release. However, items that had been used for longer than 5 years released more nickel (42.3%).

Cobalt Test Results

The cobalt test results are shown in Table 1. Cobalt was released by 206 (37.4%) of the 551 jewelry items (Fig. 1). Jewelry purchased from markets (44.2%) showed higher positive rates than those from other sources. Only 15.7% of expensive (>US \$20) items significantly discharged cobalt ($P = 0.001$). A comparison

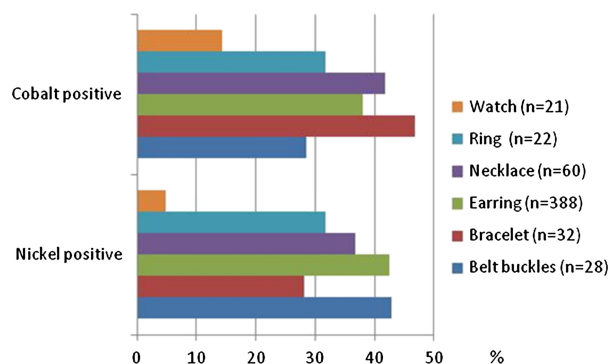


FIGURE 1. Nickel and cobalt test results for each jewelry type.

showed that colored jewelry, that is, gray (68.9%), brass (57.1%), and pink gold (55.9%), showed significantly higher positive rates of cobalt release than silver and gold jewelry ($P < 0.001$).

Eighty-four items (15.2%) concomitantly tested positive for both nickel and cobalt, and 213 items (38.7%) were negative for both metals. Of the 551 pieces tested, 338 (61.3%) were positive for either nickel or cobalt. Watches released the smallest amounts of nickel and cobalt. Jewelry bought from markets showed higher positive rates for both nickel and cobalt than that from other sources if items for which the source had been forgotten are excluded. The lower the price, the higher the amounts of nickel and cobalt detected. Older items released higher amounts of nickel and cobalt.

DISCUSSION

Nickel and cobalt are used in alloys for items such as jewelry and metal clothing items.¹² Nickel allergy is common worldwide, but cobalt allergy is uncommon in some countries.² The prevalence of nickel and cobalt allergies has increased every year,¹⁴ especially among young females, as the popularity of body piercing and the use of imitation jewelry has grown.¹⁵ Our previous study found that the incidences of nickel and cobalt allergies were 26.6% and 16.4%, respectively.⁹ Levels of nickel and cobalt allergies in Thailand are high compared with those in other countries.^{8,9} Nickel sensitization is often induced by exposure to nickel-releasing consumer items, especially imitation jewelry; the same holds for cobalt sensitization. Quantitative measurements using the EN 1811 reference method or x-ray fluorescence spectroscopy are expensive, time consuming, and potentially destructive to the test items. However, there is good agreement between the results of nickel and cobalt testing and results obtained using complex methods.^{11,13,16} The DMG test is used widely in clinical practice and by nickel-allergic individuals at home. The DMG test is cheap, quick, and easy, and has moderate sensitivity (59.3%) and high specificity (97.5%).¹¹ Test results may underestimate the amount of nickel released; nickel release of 0.5 $\mu\text{g}/\text{cm}^2$ per week or slightly higher from jewelry may not be detected. Direct comparisons

among studies are impossible. The frequency of positive DMG tests for jewelry from Thai markets was 39.2%, which is high compared with 13.9% to 18.4% in regulated European markets.^{17–19} In comparison, that for items from Korean markets was the highest (42.3%) among unregulated markets.¹² Hamann et al,³ using DMG tests, found that nickel release from earrings randomly purchased in China and Thailand was 31.5% and 29.2%, respectively. The high proportion of nickel-positive accessories in Thai marketplaces caused a higher prevalence of nickel allergy in the Thai population.⁹

Among the jewelry types tested in our study, belt buckles and earrings were the main sources of nickel exposure. Almost half of such items showed high nickel release, similar to a previous belt study, in which 55% and 60% of belt buckles purchased in the United States and China were found to release nickel, respectively.²⁰ Earrings are the greatest culprit because ear piercing is very popular. Nowadays, body piercing is also popular. Presumably, the piercing metal penetrates the epidermal barrier, allowing potential exposure to tissue fluids at the time of piercing, and afterwards, trauma or infection should occur.²¹ Watches presented the lowest nickel (4.8%) and cobalt (14.3%) release rates. Nineteen of 21 (90.5%) of our tested watches were expensive, which corresponds with our findings that significantly less nickel and cobalt were released by more expensive items. In a Dutch study,¹⁷ positive DMG tests for watches were 6 times higher (27.3%) than in our study; however, the prices were not reported in the Dutch study.

Our study showed that the jewelry source is an important factor in nickel release. Items purchased from department stores had significantly lower proportions of nickel-positive items than products bought from other places. Department stores, which are used by high-income groups, provide expensive branded jewelry. A previous study revealed that the purchase source was related to the number of DMG-positive items.²² Thyssen et al²² reported that DMG test results correlated with jewelry price, that is, inexpensive items released more nickel and cobalt.

Nickel is used as a whitening agent for white gold and increases the durability and strength. Nickel is often used as the base metal and then plated with gold or silver in costume jewelry. Inexpensive jewelry is more likely to contain higher concentrations of nickel and other allergy-producing metals than fine jewelry.²³ Exercise and perspiration while wearing jewelry exacerbate dermatitis. Heat and body salts release nickel ions, which migrate through the skin and trigger an allergic reaction.²⁴ The duration of use was considered in this study because wear and tear plays a role in nickel release. Only a small number of old items (4.7%) were collected, but nickel and cobalt releases from items older than 5 years tended to be higher. Because traces of nickel are found in many precious jewelry alloys, particularly in costume jewelry, the effects of direct prolonged contact with the skin should be considered, especially in the case of older pieces.

The EU launched the Nickel Directive 1994 (Directive 94/27/EC) to regulate nickel contents and release from jewelry and other

consumer items; it came into force in 2001. The legislation controls the amount of nickel released from products intended for direct and prolonged contact with the skin to not more than 0.5 µg/cm² per week.⁶ The enforcement of EU legislation on nickel restrictions has effectively decreased the prevalence of nickel allergy in several areas of the EU such as Denmark, Germany, Italy, and the United Kingdom.^{8,25} This type of nickel regulation has not been introduced in the United States and most Asian countries, including Thailand; however, regulations were announced in China and Korea in 2002 and 2012, respectively.^{3,12}

Cobalt is a hard metal and is commonly used in combination with other metals such as nickel, chromium, and tungsten to increase hardness and durability. Because it is often mixed with, or is an impurity in, other metals, concomitant nickel and cobalt sensitization is frequently observed.^{2,4} Nickel allergy has been controlled by regulations, but cobalt allergy will probably increase because of substitution of cobalt for nickel in inexpensive jewelry.²⁶ In Thailand, cobalt is the fourth most common allergen (16.4%), and its prevalence is higher than in many other countries.^{7,9} For jewelry from Thai markets, 37.4% of items tested positive for cobalt; this is considerably higher than reported in previous studies.^{12,26,27} This could be explained by the different test methods. We immersed the jewelry in the test solution for 5 minutes, whereas other studies used the cobalt spot test; 1 drop of the cobalt test solution was added to the white cotton stick tip, which was then rubbed against the metal surface for 20 to 30 seconds.^{12,13} In addition, a recent study from Germany revealed that 43.7% of earrings and piercing jewelry had at least 1 part releasing cobalt by quantitative analysis.¹⁶ The high level of cobalt-containing jewelry might be responsible for the high prevalence of cobalt allergy in the Thai population.⁹ Nevertheless, a recent review from Thyssen²⁸ suggested that false-positive cobalt patch test reaction is not uncommon, and dermatologists should carefully evaluate their clinical relevance.

The more expensive jewelry gave significantly fewer positive tests for cobalt. The color of metallic jewelry was also associated with the cobalt test results. We found that gray, brass, and pink gold jewelry tested positive for cobalt more often than did silver and gold items. Previous reports showed that darker-colored items released cobalt more often than lighter-colored items.²⁷ There is a 61.3% chance of buying either nickel-containing or cobalt-containing jewelry from Thai markets, reflecting the high prevalence of nickel/cobalt allergies in Thailand.

A limitation of our study was that we were unable to validate the DMG and cobalt tests using quantitative standard reference methods. However, our study shows the proportion of nickel-containing/cobalt-containing jewelry items sold in Thai markets and provides good guidance for nickel/cobalt allergy patients.

Internet trading is becoming increasingly important, and consumers can buy items directly. This is a global issue, and nickel regulation is considered to be the only way to reduce the prevalence of nickel allergy. Most of the inexpensive jewelry sold in the United States and Europe is produced in Asian countries

such as China, India, and Thailand. Legislation should be introduced, especially in the countries that are the main manufacturers of inexpensive jewelry, such as Thailand. Meanwhile, the purchase location, price, and color of jewelry can guide nickel/cobalt-allergic consumers in the purchase of such items.

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