Self-reported adverse tattoo reactions: a New York City Central Park study

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Summary

Background. Although permanent tattoos are becoming increasingly commonplace, there is a paucity of epidemiological data on adverse tattoo reactions. Several European studies have indicated that tattoo reactions may be relatively common, although the extent of this phenomenon in the United States is largely unknown.

Objectives. To provide insights into the prevalence and nature of adverse tattoo reactions.

Patients/materials/methods. We administered a survey about adverse tattoo reactions to 300 randomly selected tattooed people in Central Park, New York City.

Results. Of 300 participants, 31 (10.3%) reported experiencing an adverse tattoo reaction, 13 (4.3%) reported acute reactions, and 18 (6.0%) suffered from a chronic reaction involving a specific colour lasting for >4 months. Forty-four per cent of colour-specific reactions were to red ink, which was only slightly higher than the frequency of red ink in the sampled population (36%). Twenty-five per cent of chronic reactions were to black ink, which was less than expected based on the number of respondents with black tattoos (90.3%). Study participants with chronic, colour-specific reactions had more tattoo colours than those without reactions.

Conclusions. This study shows that tattoo reactions are relatively common, and that further investigation into the underlying causes is merited.

Key words: allergic contact dermatitis; tattoo allergy; tattoo epidemiology; tattoo reactions; tattoo survey; tattoos.

Tattoos have become commonplace in the United States; it is estimated that one-quarter of the population has at least one permanent tattoo (1). The increasing popularity of cosmetic tattoos in the form of permanent makeup since the 1970s has added further to the proportion of the population exposed to tattooing (2). There is limited statistical information on adverse tattoo reactions, but the available data suggest that they are becoming more common. Whereas only 5 cases of adverse reactions were reported to the United States Food and Drug Administration (FDA) between 1988 and 2003, from 2003 to 2004, there were reports of >150 adverse reactions to permanent makeup procedures alone (2). Understanding the nature and prevalence of tattoo reactions is important, as they can be quite distressing: a Danish study in a dedicated 'tattoo clinic' surveyed patients with tattoo reactions lasting for >3 months, and found that patients reported troublesome persistent symptoms, such as

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itching, pain, soreness, and stinging, that had a significant impact on their quality of life, affecting daily and leisure activities (3).

There is a growing body of literature on the prevalence of tattoo complications in Europe, although researchers have used a variety of methods and definitions of reaction types, which makes it somewhat difficult to make comparisons among studies. A recent internet survey of 3411 tattooed respondents from German-speaking countries recruited from a variety of advertisements, including a press agency report placed in almost all of Germany's local newspapers, showed that 67.5% of respondents had experienced an immediate adverse tattoo reaction, 8% reported still having a reaction 4 weeks after obtaining the tattoo, and 6% reported a persistent ongoing reaction consisting of oedema, permanent elevation of skin, and pruritus (4). A study of consecutive patients at a sexually transmitted disease clinic in Copenhagen found that, of 154 patients with 342 tattoos, 15% reported early complaints (up to 3 months) such as itching, ulceration, redness and swelling, prolonged healing, and infection, and 27% reported a variety of complaints with a tattoo 3 months or more after they obtained it (5). Another Danish survey conducted on several beaches found that, of 144 sunbathers with 301 tattoos, 42% had complaints, which were most commonly swelling, itching, stinging, pain, and redness, 52% of which were light-induced (6). Authors affiliated with a Bulgarian dermatology clinic reported the overall prevalence of tattoo complications in a series of patients to be 2.1% (5 of 234 patients), including infectious, allergic and/or granulomatous responses (7).

There is no corresponding literature on populations in the United States, and there is currently no centralized database tracking this information; therefore, the extent of adverse events is unknown. Furthermore, tattoo ink components are not regulated by the US federal government. The Food, Drug, and Cosmetic Act of 1938 lists tattoo pigments as colour additives that are intended for topical use only, none of which are approved for injection into the skin, and the agency has never implemented inspection of tattoo pigments (8). In contrast to the European studies cited above, published accounts in the United States are primarily case studies, and do not provide information on the prevalence rates of different types of tattoo reaction among the general population, although our clinical experience suggests that tattoo reactions are not uncommon.

Chronic, colour-specific tattoo reactions have been reported in the literature for almost every ink colour (9), with reactions ranging from acute processes, such as delayed healing and infection, to more chronic events, such as keloids, allergy, autoimmune responses, and malignancy (7, 10–12). Red ink, in particular, has been commonly reported in association with tattoo reactions (7, 13–15). The composition of modern tattoo ink, however, is poorly understood. Black ink is composed of soot derivatives and carbons, including polycyclic aromatic hydrocarbons, and this has not changed radically over the last several decades. The composition of colour inks, however, has changed since the 1970s. Whereas heavy metals – such as mercury, cadmium, and lead – were previously key ingredients in tattoos, the US FDA banned the use of these substances for cosmetic purposes in the 1970s. They are no longer common components of tattoo inks (16, 17), and synthetic organic pigments, such as azo dyes and polycyclic compounds, are now more frequently used (18, 19). Whereas there is a growing body of literature on the safety of tattoo inks, and many steps have been taken towards stricter regulation of tattoo inks in Europe over the last decade, the regulation and investigation of tattoo safety in the United States is not as developed (11, 18, 19).

Given the limited epidemiological data on tattoos, we sought to gather information on the prevalence of adverse tattoo reactions in a tattooed population. In this study, we report the results from a survey of 300 randomly selected tattooed people in Central Park in New York City. Our objectives were to estimate the prevalence rates of self-reported acute and chronic tattoo reactions, including colour-specific reactions, determine whether people sought medical attention for these events, and describe the characteristics of acute and chronic tattoo reactions. We gathered information about colours associated with chronic tattoo reactions, asked whether reactions were more common when people had more tattoo colours, and determined whether chronic allergic reactions were more likely in people with other self-reported allergies.

Methods

Study design and mechanics

After conducting a literature review of the clinical characteristics of adverse tattoo reactions, we designed an anonymous, 17-question survey using branched logic (Table 1). The survey was approved by the NYU Institutional Review Board (Protocol no. S13-00796). Survey data were collected in New York City's Central Park, an area popular with tourists and residents from a broad socioeconomic range, on 8 weekend days and 4 weekdays in June 2013, with the aim of collecting surveys from the first 300 tattooed individuals who met the eligibility criteria (discussed below) and consented to participate in the study. The park was divided into two sections,

Table 1. Adverse tattoo reaction survey questions

1. What is your age?
2. Are you a male or female?
3. What is your citizenship status?
4. Do you consider your natural skin tone to be very fair, fair, medium, dark, or very dark?
5. What is your ethnicity?
6. How many tattoos do you have?
7. Where are these tattoos located on your body?
8. What total percentage of your body's surface area is covered by tattoos? (Estimated by surveyor using 'rule of 9s')
9. What is the age your tattoos? If you have many tattoos, what is the age of the newest and oldest tattoos?
10. What ink colours were used in your tattoos?
11. In what geographical location was each tattoo performed?
    a. Do you remember the name of the tattoo parlour?
12. Do you have any known food, drug, or other allergies? If yes, to what?
13. Do you have any history of experiencing an adverse tattoo reaction? (A tattoo reaction can be considered any skin sign or symptom that differs from what you would consider a normal part of tattooing or tattoo healing. This can include, but is not limited to, persistent redness, itching, rash, irritation, swelling, scarring, infection, disfigurement, raising, and photosensitivity which you consider beyond the normal expectations for tattooing and tattoo healing.)
    a. If no, you may end the survey here.
    b. If yes, please describe the adverse reaction in your own words, then continue to question 14.
14. Which tattoo was involved?
    a. How old was the tattoo when the reaction began?
    b. Were there any particular colors of ink involved?
    c. Where is the involved tattoo located on your body?
15. Did you report this reaction to the tattoo parlor where you received the tattoo?
16. Did you seek medical attention for the tattoo reaction? If yes:
    a. What type of health care provider did you see?
    b. Were you given any specific diagnosis?
    c. Were you administered, prescribed, or told to use any topical, oral, or injectable medications for treatment of the reaction? If yes:
        i. Did the reaction resolve with treatment?
17. If you are currently experiencing a tattoo reaction (with or without prior treatment), how long have you been experiencing this reaction?
    a. What symptoms still persist?

north and south of 79th street, and individual persons or groups of people encountered at leisure in Central Park were approached.

The surveyors, 2 medical students, introduced themselves and the purpose of the study, and asked potential participants whether they had any tattoos that they would be willing to discuss for the purposes of the investigation. If a person did have a tattoo and verbally consented to participate in the study, the person was given an information sheet that contained the background, purpose and contact information for the study. If a group was approached with more than 1 eligible participant, only 1 individual's information was collected, in order to reduce the possibility that people in the group may have received tattoos from a similar geographical area or tattoo parlour. Participants were told that they could end the survey at any time or choose to omit answering questions that they felt to be intrusive or irrelevant. The only question omitted by choice by any of the participants was age, and these participants were labelled as 'unknown' in any data regarding age. A verbal survey was then administered to individuals, with answers being recorded by the surveyors. All eligible participants completed the branched survey to the appropriate point according to their personal history of exposure to an adverse tattoo reaction. The surveyors did not interrupt, interfere with or correct responses. The investigators estimated the body surface area of the tattoos by using the Wallace rule of nines. When possible, the surveyors evaluated the tattoos themselves to determine size. When this was not possible, respondents were asked to use their palms (representing 1% body surface area) to indicate the size of their tattoos.

Study participants and data analysis

Eligibility criteria included age of at least 18 years, one tattoo having been performed in the United States, and the ability to read and understand English. Surveys were administered to the first 308 encountered persons with tattoos who consented to participation and met the eligibility criteria. In 8 cases, participants were deemed ineligible when it was found that all of their tattoos were received outside of the United States, and the data from these participants were not used in the analysis. Approximately 5–10% declined to join after the

surveyors introduced themselves and described the study, most citing time concerns.

For the purposes of this study, we defined adverse tattoo reactions as 'any skin sign or symptom that differs from what you would consider a normal part of tattooing or tattoo healing' (Table 1). We defined acute reactions as lasting for <4 months, including descriptions of occurrences such as infection or delayed healing, and chronic reactions as lasting for >4 months, including one or more of the following associated symptoms: itching, scaling, swelling, persistent elevation, or scarring. Self-reported food, drug or other allergies were analysed as a unit, owing to uncertainty about underlying causes.

We compiled response data of all participants, and ANOVA was used to determine whether participants with no reaction, acute reactions or chronic, colour-specific reactions differed in the number of tattoos, area covered with tattoos (presented as an estimate of the percentage of skin surface area with tattoos), and number of tattoo colours. Because of the likelihood of positive correlations between the number of tattoos, tattooed area, and the number of tattoo colours, we conducted a second analysis to determine whether participants with chronic reactions had more tattoo colours than other participants, after controlling for the number and size of their tattoos. This was performed with ANCOVA, with the type of reaction, the number of tattoos and tattooed area included in the model, with the last two factors being included as continuous covariates. Finally, a chi-square test was used to determine whether participants with other types of allergies were more likely to have tattoo reactions than other participants. Analyses were conducted in JMP v. 11.0.0 (SAS Institute, Cary, NC, USA), with significance measured at $p < 0.05$. Values in the text and figures are either raw data or means ± standard errors.

Results

Participant demographics (Table 2)

Approximately equal numbers of male and female participants were surveyed, the majority (265/300; 88.3%) of whom were US citizens. The reported age of participants ranged from 18 to 69 years, with 2 participants not disclosing their age. A history of allergy was reported by 103 of 300 (34.3%) participants, most commonly to foods and antibiotics, and seasonal allergic rhinitis, although animal and other allergies were also reported

Tattoo characteristics (Table 3)

The majority of participants surveyed had fewer than five tattoos, with 53 being the largest number of tattoos reported, and the average number of tattoos being 4.7. The estimated area covered by tattoos ranged from 0.5% to 90%, and the average area covered was 7.2%. The most common tattoo location was the arm (67.7%), including the hand, wrist, and shoulder, but almost all areas of the body were reported to have tattoos. A full spectrum of colours was reported in participants' tattoos. The most common colour was black, and >90% of participants reported having black ink in at least a portion of their tattoos. Other common colours included red (36.0%), blue (30.3%), and green (28.0%); many other colours were present to lesser degrees (Table 3). Participants had average of 2.5 colours on their body, and 134 (44.7%) of participants had only one colour; the vast majority (91%) of single-colour tattoos were black. There was a significantly positive relationship between the number of tattoos and the number of colours ($p < 0.0001$), but there was a lot of variation, and the overall explanatory power was low ($r^2 = 0.11$). The oldest reported tattoo was 41 years old, and the newest was 1 week old.

Table 2. Demographics of 300 participants interviewed in Central Park, New York City

Category	Characteristics	No. with characteristic	% with characteristic
Sex	Male	149	49.7
	Female	151	50.3
Citizenship	US citizen	265	88.3
	Foreign citizen	35	11.7
Age (years)	18–19	9	3
	20–29	175	58.3
	30–39	82	27.3
	40–49	20	6.7
	50–59	9	3
	60–69	3	1
	Unknown	2	0.7
Allergy status	No allergies	197	65.7
	Allergies	103	34.3
Type of allergy	Foods	42	40.7
	Animals	15	14.6
	Seasonal/environmental	32	31.1
	Antibiotics	29	28.2
	Other	11	10.7

Prevalence and characteristics of acute and chronic reactions

Adverse tattoo reactions were reported by 10.3% (31/300) of survey participants. Thirteen of the 31 cases, representing 4.3% of participants, were acute adverse reactions that ranged in duration from a few days to 4 months. These reactions most often occurred a few days to weeks after tattoo placement, and included pain

Table 3. Tattoo characteristics of 300 participants interviewed in Central Park, New York City

Category of characteristic	Characteristic	No. with characteristic	% with characteristic
Number of tattoos	1	92	30.7
	2	48	16.0
	3	49	16.3
	4	34	11.3
	5	13	4.3
	6–10	36	12.0
	11–20	18	6.0
	≥21	10	3.3
Body part with tattoo	Arm	203	67.7
	Back	106	35.3
	Leg	98	32.7
	Flank/abdomen	66	22.0
	Chest	50	16.7
	Hips	33	11.0
	Neck	32	10.7
	Head	9	3.0
	Genitals	4	1.3
	Buttocks	3	1.0
	Outer lip	3	1.0
	Inner lip	3	1.0
Colours in tattoos	Black	271	90.3
	Red	108	36.0
	Blue	91	30.3
	Green	84	28.0
	Yellow	63	21.0
	Purple	45	15.0
	Orange	36	12.0
	Pink	31	10.3
	White	14	4.7
	Grey	10	3.3
	Brown	10	3.3
	Rust	2	0.7
	Peach, magenta, or fluorescent green	1	0.3

at the tattoo site, infections requiring antibiotics, itching, swelling, and prolonged scabbing.

Eighteen of the 31 cases, representing 6.0% of the survey population, were chronic, lasting for >4 months. Chronic reactions were all colour-specific (Table 4), and were described as itchy, scaly, raised, oedematous, or a combination of these symptoms, involving only specific colours within a tattoo. Two chronic cases were described as 'scarring.' One colour-specific reaction was described as being triggered by sun exposure. Another participant described a red reaction developing 2 weeks after a new tattoo, with subsequent development of a similar response in the red ink portion of an 8-year-old tattoo. The onset of chronic reactions as participants described them ranged from 'immediately' to 4 years after tattoo acquisition. Almost two-thirds of participants with chronic reactions reported immediate reactions (11/18; 61.1%), and the majority of these respondents (16/18; 88.9%) reported experiencing ongoing symptoms. Less than one-third of respondents with any type of adverse reaction (9/31; 29%) had obtained medical care for their symptoms, with only 5 participants, all with chronic reactions, seeking care from dermatologists. Most treatments included topical or intralesional corticosteroids.

Participants with acute reactions had significantly more tattoos (15.7 ± 1.7) and greater tattooed area ($17.3 \pm 2.6\%$) than participants with chronic colour-specific reactions (tattoo number, 7.1 ± 1.4; area, $9.4 \pm 2.2\%$) or participants who reported no reactions (tattoo number, 4.0 ± 0.4; area, $6.5 \pm 1.0\%$; tattoo number, $F_{2,297} = 25.1$, $p < 0.0001$; area, $F_{2,297} = 9.0$, $p = 0.0002$). Additionally, participants with both chronic and acute reactions had significantly more tattoo colours than participants with no reaction (acute, 4.0 ± 0.5; chronic, 4.2 ± 0.5; no reaction, 2.4 ± 0.1; $F_{2,297} = 11.9$, $p < 0.0001$). After accounting for differences in the number of tattoos and area covered, there were still significant differences among participants with and without reactions ($F_{2,291} = 8.1$, $p = 0.0004$). Specifically, participants with chronic reactions had significantly more colours than other participants, but participants with acute reactions no longer differed from other participants with respect to the number of colours in their tattoos (Fig. 1).

The two ink colours most commonly involved in chronic colour-associated reactions were red (8/18) and black (6/18), although other colours were also reported (Table 4). Forty-four per cent of chronic reactions were to red ink, which is a somewhat higher frequency than would be expected based on the frequency of red ink in respondents' tattoos (36%). Thirty-three per cent of chronic reactions were to blank ink, which was a lower frequency than would be expected based on the prevalence of black ink among participants (90.3%).

There were significant differences in self-reported allergies among participants with tattoo reactions ($\chi^2 = 6.1$, $p = 0.0475$). Of respondents with chronic colour-specific reactions, 61.1% (11/18) reported having allergies, versus an allergy prevalence of 38.5% (5/13) in respondents with acute reactions and of 32.7% (88/269) in participants with no reaction.

Discussion

Although various types of tattoo reactions have been reported in the literature, the prevalence of tattoo reactions among tattooed persons remains uncertain,

Table 4. Chronic colour-specific reaction characteristics

Age (years)/ sex	No. of tattoos	Area (%)	Tattoo colours	History, status, and symptoms	Onset	Duration	Doctor (MD), treatment
34/M	6	18	**bk, ru,** bl, br, r	Soft, red, crusting, raised, delayed healing, remains elevated; unresolved	Immediate	11 years	No MD, topical lotion
31/M	11	15	**gf,** g	Itchy, worse with seasonal allergies; unresolved	Immediate	6 years	No MD
31/F	3	5	**pk, r,** bk, bl, g	Itchy, elevation, 'red bumps' over pink and red areas; unresolved	4 years	1 year	MD, steroid cream
33/M	40	30	**bk,** bl, o, pu, r, y	Elevation, worse with seasonal allergies; unresolved	0.5–1 year	Unknown	No MD, lotion
26/F	10	9	**r,** bk, bl, g, o, pu, y	Immediate elevation for a few months, reoccurs periodically; unresolved	Immediate	Unknown	MD, antibiotics
26/F	4	9	**r,** bl, g, pk, pu, y	'Red bubbles' and extremely itchy and raised over red while healing, remains itchy, elevated, scaly; unresolved	Immediate	1 year	MD, topical steroids
34/F	5	5	**w,** bk, pe, pk	Initially infected, now elevation with 'pink/red dots'; unresolved	Immediate	6 months	MD, steroid injections
32/F	3	5	**pu, r,** bl, g, y	Itchy, elevation; unresolved	Immediate	7 years	No MD
NA/F	5	2	**r, y,** bl, bk	Itchy, elevation, colours 'faded'; unresolved	3 years	7 years	MD, petroleum jelly, steroid injections
33/F	1	2	**bk,** bl, g, o	Itchy, elevation of tattoo 'outline' after initial healing; resolved	6 months	1 year	No MD, OTC topical steroids
35/F	3	3	**w,** bk, pk	Itchy, elevation, delayed healing, 'wrinkly skin', scaly; unresolved	Immediate	2 years	MD*, topical and injectable steroids
29/F	2	2	**bk**	Itchy, elevation, worse with seasonal allergies; unresolved	Immediate	5 years	No MD
26/M	7	9	**r,** bk, g, w, y	Elevation, associated with seasonal allergies; unresolved	6–9 months	1.5 years	No MD
34/F	1	1	**bk**	Itchy, delayed healing, elevation with light exposure; unresolved	Immediate	19 years	No MD, petroleum jelly
46/F	10	18	**r,** bl, bk, g, pk, pu, y	Itchy, elevation, swelling, scaly; resolved	1 month	8 years	MD*, topical steroid
34/M	7	15	**r,** bk, bl, g	Itchy, elevation of red 2 weeks after tattoo; 1 week later, same response in red of 8-year-old tattoo. All red ink involved; unresolved	2 weeks	3 months	MD, topical steroids
27/F	9	18	**bk,** bl, br, g, pk, pu, o, r, y	'Bad scarring', raised since the healing process; unresolved	Immediate	Unknown	No MD
27/M	1	3	**bk**	Raised and scarred; unresolved	Immediate	10 years	No MD

bk, black; bl, blue; br, brown; F, female; g, green; gf, fluorescent green; M, male; NA, not available; o, orange; OTC, over the counter; pe, peach; pk, pink; pu, purple; r, red; ru, rust; w, white; y, yellow.
Colours associated with colour-specific reactions are in bold.
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especially outside of European populations. The acquisition of this data in the United States is complicated by a lack of FDA regulation, by the absence of a centralized reporting system for adverse tattoo events, and because those experiencing tattoo reactions often do not seek medical care. From our own clinical experience, we hypothesized that adverse tattoo reactions were relatively common. Indeed, in our survey, >10% of people with tattoos reported some type of adverse tattoo event, with 6% of tattooed individuals reporting a chronic, colour-specific reaction. This relatively high rate of adverse events is consistent with one study (4), but much lower than the rates found in two Danish studies (5, 6) that sought to more broadly evaluate patient complaints about any deviation from normal skin sensation or appearance. For the vast majority of people who we surveyed, these chronic, colour-specific reactions are ongoing and have remained unresolved for many years, even for participants who have sought medical treatment. It is of note that only approximately one-third of those surveyed

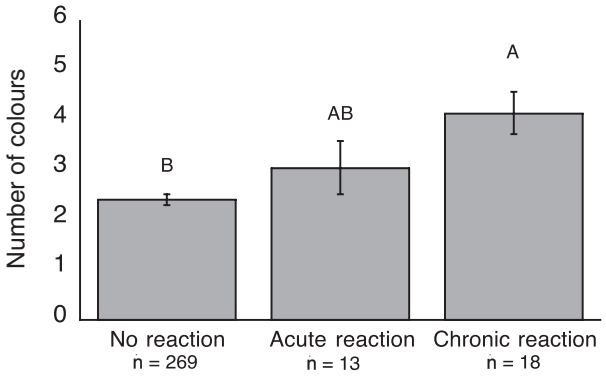

Fig. 1. Comparisons of the number of tattoo colours among participants who reported no reaction, acute reactions lasting for <4 months, or chronic colour-specific reactions lasting for >4 months, after accounting for differences in tattoo number and tattoo area among groups. Significant ($p < 0.05$) differences among groups, determined with Tukey's HSD tests, are represented by different letters.

sought medical care for their tattoo complaints, a figure that, even though low, is slightly higher than reported in the studies addressing tattoo complaints (5, 6).

It is not possible to derive a precise diagnosis of chronic tattoo reactions from the self-reported symptoms of our survey participants. Indeed, it is difficult to know precisely what kind of information we captured by asking patients whether they had ever experienced an adverse tattoo reaction defined as 'any skin sign or symptom that differs from what you would consider a normal part of tattooing or tattoo healing.' Although some of the positive responses that we discuss here may have been more consistent with minor complaints than with true adverse reactions, we suspect that this was not the case for most respondents. Indeed, if our data are compared with the Danish results, it seems more likely that we did not capture all minor patient complaints and discomforts with their tattoos, as the number of complaints was much higher in the Danish studies. The classification of adverse tattoo reactions is not straightforward, even under controlled clinical circumstances (9). A recent literature review of adverse tattoo events in 280 patients divided them into three categories: infectious, malignant and inflammory/immune reactions. Of these, approximately one-third (96) fit into the third category, with granulomatous, lichenoid or hypersensitivity allergic reactions presenting days to years after the tattoo had been placed. It is particularly challenging to classify this subset of inflammatory delayed chronic reactions, as the authors note. Clinically, there is much variability, and histologically these reactions can show a variety of inflammatory patterns, including eczematous, lichenoid, granulomatous, lymphohistiocytic, and pseudolymphomatous (9, 20–22).

Classifying a tattoo reaction specifically as an 'allergy' is additionally challenging. There is a subset of patients described in the literature (and 1 in our study who gave this classic clinical history) who have clearly developed a particular reaction to a specific colour after repeat exposures, which is characteristic of a type IV allergic reaction (23–25). More commonly, patients present with erythema, pruritus, induration and/or swelling confined to the tattoo or a portion of the tattoo, but, histologically, these reactions are variable and inconsistent, presenting the same range of patterns as the general inflammatory tattoo reactions (9, 15). It is of note that type I and type III allergic reactions have also been described in association with tattoos (15). Patch testing, however, is an unreliable way to confirm suspected tattoo allergies. In a recent study of 90 patients with chronic tattoo reactions, even when the individual inks known to be responsible for the reaction were available, patch testing was mostly negative or clinically insignificant (25). Even prick testing has not been shown to be a reliable way of diagnosing tattoo reactions (26). Serup and Hutton Carlsen hypothesize that the unreliability of patch testing for diagnosing tattoo allergies may be attributable to the fact that the allergen itself is a byproduct of the tattoo ink, because the tattoo pigments – azo dyes in particular – are poorly soluble and unable to elicit a reaction when applied topically, and/or because the allergens are formed in the dermis via a process of haptenization (25). Because of these difficulties in making a definitive diagnosis of tattoo allergy, one set of authors has suggested the term 'tattoo-induced immunologic reaction' to encompass this broad category of chronic tattoo reactions (15). This terminology has the advantage of highlighting the fact that immune reactions associated with tattoos may be highly variable. Even patients with clearly immune-mediated reactions (e.g. those who, with repeat exposures, develop reactions in a particular ink colour) can have a variety of histological and clinical patterns associated with their tattoos. The problem with using this terminology too broadly, however, is that it may mischaracterize reactions that are not truly immune-mediated as immunological. This terminology would not, for example, adequately capture the suspected mechanism whereby black inks can cause tattoo complaints, which is thought to be attributable to the production of reactive oxygen species that may be linked to the aggregation of nanoparticles in particular inks (27, 28).

In our survey, red and black inks were most commonly associated with chronic tattoo reactions, and the association with red ink was somewhat different from what

would be expected from the distribution of red ink tattoos in our study population. Whereas it is appreciated that red tattoos are often associated with tattoo reactions (13, 15, 25), there has been some inconsistency in the literature regarding how often black tattoos cause reactions. For example, in the Wenzel literature review, 83.3% of the inflammatory tattoo reactions were associated with coloured ink, and only 12.5% were associated with black ink – a finding that was also reflected in the team's German-language tattoo survey (9). However, in the Danish sexually transmitted disease clinic study, most complaints after 3 months (85%) were linked to black tattoos, including many photosensitive reactions, with only 9% being linked to red tattoos (5). In the Danish beach study, photosensitive reactions were most frequently reported in black and red tattoos (6). There are probably different mechanisms for the production of reactions to black and to red inks, as discussed above. Black and red inks, however, are also the most common inks used in tattooing (9); thus, larger studies are needed to determine whether red and black tattoo reactions occur disproportionately to the use of these ink colours in tattooed populations. Although red and black inks were common sources of adverse reactions in our study, we also observed a relationship between exposure to a larger number of colours and the likelihood of a chronic tattoo reaction. This may suggest that repeat exposures to particular coloured inks can result in an immunogenic response; however, larger studies would be needed to understand this association.

We also observed an association between self-reported allergies and chronic, colour-specific reactions: almost two-thirds of participants reporting a chronic adverse tattoo reaction also reported a history of allergies, whereas just over one-third of participants with no tattoo reactions reported allergies. Several participants with tattoo reactions associated the fluctuating severity of the reaction with the status of their pre-existing allergy. These data must be interpreted with caution, as the reported allergies – described simply 'as any known food, drug, or other allergies' – were not verified by a physician.

Finally, our study was a small survey of participants in one location, and sampling error or bias may therefore exist. The choice of Central Park as a venue allowed for a rapid survey of a diverse population, but may have influenced the age and socioeconomic status of respondents. For example, the majority of our respondents were aged <30 years. In addition, because reactions were self-reported and not evaluated clinically, we are unable to ascertain the precise nature of reported reactions, which probably span a wide range of conditions. Despite these limitations, our results suggest that chronic tattoo reactions are relatively common, although they may be under-reported, and future studies of larger populations are warranted. Although it would be ideal to gather additional data from clinical evaluations, the reluctance of people to seek medical attention for tattoo reactions indicates that a survey approach, as employed here, may be more effective in identifying the prevalence and nature of tattoo reactions in the general population.

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