



A comprehensive health effects assessment of the use of sanitizers and disinfectants during COVID-19 pandemic: a global survey

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Abstract

COVID-19 has affected all aspects of human life so far. From the outset of the pandemic, preventing the spread of COVID-19 through the observance of health protocols, especially the use of sanitizers and disinfectants was given more attention. Despite the effectiveness of disinfection chemicals in controlling and preventing COVID-19, there are critical concerns about their adverse effects on human health. This study aims to assess the health effects of sanitizers and disinfectants on a global scale. A total of 91,056 participants from 154 countries participated in this cross-sectional study. Information on the use of sanitizers and disinfectants and health was collected using an electronic questionnaire, which was translated into 26

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languages via web-based platforms. The findings of this study suggest that detergents, alcohol-based substances, and chlorinated compounds emerged as the most prevalent chemical agents compared to other sanitizers and disinfectants examined. Most frequently reported health issues include skin effects and respiratory effects. The Chi-square test showed a significant association between chlorinated compounds (sodium hypochlorite and per-chlorine) with all possible health effects under investigation (p -value < 0.001). Examination of risk factors based on multivariate logistic regression analysis showed that alcohols and alcohol-based materials were associated with skin effects (OR, 1.98; 95%CI, 1.87–2.09), per-chlorine was associated with eye effects (OR, 1.83; 95%CI, 1.74–1.93), and highly likely with itching and throat irritation (OR, 2.00; 95%CI, 1.90–2.11). Furthermore, formaldehyde was associated with a higher prevalence of neurological effects (OR, 2.17; 95%CI, 1.92–2.44). Furthermore, formaldehyde was associated with a higher prevalence of neurological effects (OR, 2.17; 95%CI, 1.92–2.44). The use of sodium hypochlorite and per-chlorine also had a high chance of having respiratory effects. The findings of the current study suggest that health authorities need to implement more awareness programs about the side effects of using sanitizers and disinfectants during viral epidemics especially when they are used or overused.

Keywords COVID-19 · Sanitizers and disinfectants · Side effects · Health protocols

Introduction

COVID-19 is one of the great challenges to human health. According to the report of the World Health Organization, by November 16, 2022, 548 million people were infected and more than 6 million deaths worldwide had occurred (WHO, 2022). The emergence of new and mutated strains of the virus over time and the production of less effective vaccines have exacerbated this catastrophic health challenge (Hashemi et al., 2022b; Viveiros-Rosa et al., 2022). From the beginning of the COVID-19 outbreak, simultaneously with treatment measures, health and preventive measures such as strict quarantine, social distancing, hand washing, disinfection of various surfaces, and wearing a mask among others, as health protocols to reduce and cut off the transmission chain were on the agenda of governments and health organizations (Alimohamadi et al., 2022a; Amanollahi et al., 2021; Hashemi et al., 2022b; Sharun et al., 2022). With the hypothesis of the persistence of the virus on different surfaces and its transmission through skin contact, personal and public hygiene by hand washing and disinfection of different surfaces became more important. Among the various surfaces with the most frequent contact were door handles, smartphones, remote controls, keyboards, tables and chairs, light switches, and elevator buttons, etc. (Al-Sayah, 2020; Ghafoor et al., 2021; Jin et al., 2020; Yari et al., 2020). The literature shows that SARS-CoV-2 can float in the air for 3 h, on smooth surfaces (glass, plastic, banknotes) for 4 to 7 days, on the outer layer of the surgical mask for up to 7 days, on copper surfaces, cardboard, and paper for less than 3 h and stainless steel up to 72 h (Chin et al., 2020; Dhama et al., 2021; Doremalen et al., 2020). The shelf life of the virus depends on various factors such as temperature, relative humidity, and pressure (Dindarloo et al., 2020; Gharehchahi et al., 2023; Kampf, 2020). To reduce the spread of

the virus and disrupt the transmission chain, disinfection using sanitizers and disinfectants for living and non-living surfaces as an efficient method was recommended by the World Health Organization (WHO) and the US Environmental Protection Agency in accordance with the issued instructions (Chen et al., 2021; Dindarloo et al., 2020). Sanitizers and disinfectants used include alcohol-based materials, oxidizing agents, detergents, chlorine-releasing agents (sodium hypochlorite, per-chlorine), phenol-based disinfectants, iodine-releasing agents, aldehydes, hydrogen peroxide, and quaternary ammonium compounds, etc. (Al-Sayah, 2020; McDonnell and Russell, 1999; Rutala and Weber, 2019). Using sanitizers and disinfectants may have adverse effects on human health, mainly because of the harmful and corrosive compounds in the composition of most sanitizers and disinfectants, such as chlorine-releasing agents, quaternary ammonium cations, or oxidizing agents (Bonin et al., 2020; Dumas et al., 2019; Emmanuel et al., 2004; Nabi et al., 2020; Rafiee et al., 2022). The severity of these side effects may vary depending on the type of chemicals, their target objects (living or non-living surfaces), the frequency and volume of the chemicals, and the risk status of the exposed individual (Prajapati et al., 2022). Lack of knowledge and insufficient experience in sanitizer and disinfectant use increases the rate of side effects due to the use of these chemicals (Gharpure et al., 2020; Rai et al., 2020). Potential acute side effects of using sanitizers and disinfectants include skin effects, itching, sore throat, eyes, and nose irritation, and ailments of the respiratory system (cough, sneezing, shortness of breath). Neurological effects such as headache, dizziness, and vomiting have been also reported (ECDC, 2020; Goh et al., 2021; Lachenmeier, 2008). Regardless of the sanitizer and disinfectant safety information and application instructions prolonged use of these products may cause chronic side effects including disorders of the central nervous system (CNS),

reproductive disorders, cancer, pulmonary obstruction, etc. (Choi et al., 2020). Although several studies have been conducted regionally in a variety of countries on some of the adverse health effects due to disinfectant use (Dawood et al., 2021; Dhama et al., 2021; Dindarloo et al., 2020; Ghafoor et al., 2021; Rosenman et al., 2021; Shah et al., 2021), the present study is a comprehensive survey aimed to estimate the health effects associated with the use of sanitizers and disinfectants among the general population on a global scale.

Methods

Design, participants, and sampling procedure

This study aims to assess the health effects of sanitizers and disinfectants on a global scale. There were no exclusion/inclusion criteria for participation in the study, and all individuals regardless of race, gender, occupation, and income level were included. The research project was approved by the ethics committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1400.023). This study follows the principles of the Declaration of Helsinki. Survey design (non-interventional) is not considered a clinical trial under Directive 2001/20/EC and Regulation (Europe) No 536/2014. All participants provided online informed consent before the study.

Measurement tools

Questionnaire

The questionnaire was translated into 26 different languages by native language speakers. The questionnaire included three parts (including 26 items). The first part (7 questions) was referring to demographic information including age, gender, educational and occupational status, country, place of residence, and income level. The second part (6 questions) included the type, monthly usage volume, and the number of daily use of sanitizers and disinfectants for living and non-living surfaces. The chemicals which have been investigated included detergents (soap and toilet liquid, dishwashing liquid), alcohol or alcohol-based materials, hospital-grade sanitizers (savlon; antiseptic liquid), other commercial sanitizers (chlorhexidine gluconate, bronopol, triclosan), hospital disinfectants (quaternary ammonium, tetra-acetyl ethylenediamine), chlorine-based compounds (sodium hypochlorite, per-chlorine), hydrogen peroxide, and formaldehyde. The third part (13 questions) included health effects. Skin effects (itching and skin irritation, dryness, scaling, and urticaria), ocular (itching and eye irritation, and redness), irritation and itching of the throat, respiratory problems (itching and nasal irritation, runny nose, cough and sneezing, and shortness of breath), and

neurological effects (headache, dizziness, and vomiting) were questioned. Questionnaire-related questions and options were reviewed by several specialists, including a dermatologist, otolaryngologist, ophthalmologist, pulmonologist, and chemist, as well as a biostatistics specialist.

Reliability and validity

The reliability of the questionnaire showed good internal consistency (Cronbach's $\alpha = 0.90$). The validity of the questionnaire for only seven living languages (Arabic, English, French, German, Persian, Russian, and Spanish) which are considered official or secondary languages of several countries, was reviewed by 5 to 7 experts in each of the 7 languages with research backgrounds related and faculty members. These experts assessed the validity in light of five components of necessity, relevance, transparency, simplicity, and ambiguity related to each question.

Data collection procedure

The questionnaire was designed using Google Form®. In some countries (e.g., China), lack of access to Google or due to poor bandwidth, other internal platforms (e.g., wenjuanxing) and sites (e.g.; <https://www.wjx.cn/>) were used to create online links to the questionnaire. The questionnaire was distributed via email or social networks such as Telegram, WhatsApp, Instagram, Twitter, LinkedIn, and WeChat. The questionnaire was available online for 9 months from August 1, 2021 to April 30, 2022 to achieve maximum participation.

Statistical analysis

The data were analyzed using IBM SPSS for Windows, version 28.0 (IBM Inc., Armonk, NY, USA). The Chi-square test was used to analyze descriptive statistics (n, %), and to evaluate the significance of the association between variables. To assess risk factors for health outcomes in participants, a multivariable logistic regression analysis was performed, and the relationship between risk factors and adverse effects of using sanitizers and disinfectants are presented as odds ratios (ORs) and 95%CIs, after adjustment for confounders, including age, gender, educational level, occupational status, place of residence (rural and urban areas), and income level. A *p*-value of <0.001 was considered statistically significant.

Result

Study design and participants

Demographic characteristics are shown in Table 1. A total of 91,056 participants [58,845 (64.60%) females and 32,211

Table 1 Demographic characteristics of the study ($N = 91,056$)

Characteristics		N	Male	Female	
Age	≤20	9861(10.8)	3502(3.8)	6359(7.0)	
	21 to 30	37,577(41.3)	12,637(13.9)	24,940(27.4)	
	31 to 40	22,250(24.4)	8093(8.9)	14,157(15.5)	
	41 to 50	13,338(14.6)	4744(5.2)	8594(9.4)	
	51 to 60	5746(6.3)	2150(2.4)	3596(3.9)	
	60 and over	2284(2.5)	1085(1.2)	1199(1.3)	
Place of residence	Urban	76,122(83.6)	25,987(28.5)	50,135(55.1)	
	Rural	14,934(16.4)	6224(6.8)	8710(9.6)	
Level of education	School education	14,784(16.2)	5662(6.2)	9122(10.0)	
	Associate degree	12,546(13.8)	3673(4.0)	8873(9.7)	
	Bachelor’s degree	38,924(42.7)	13,457(14.8)	25,467(28.0)	
	Masters	16,798(18.4)	6348(7.0)	10,450(11.5)	
	Ph.D. and postdoctoral	8004(8.8)	3071(3.4)	4933(5.4)	
Occupational status	Unemployed / housewife / student	12,571(13.8)	2443(2.7)	10,128(11.1)	
	University Student	28,104(30.9)	9489(10.4)	18,615(20.4)	
	Government employee	26,249(28.8)	10,038(11.0)	16,211(17.8)	
	Private office employee	16,619(18.3)	645(7.0)	9974(11.0)	
	Freelance (self-employed)	7513(8.3)	3596(3.9)	3917(4.3)	
Income	Low	8877(9.7)	3004(3.3)	5873(6.4)	
	Lower-middle	11,339(12.5)	4325(4.7)	7014(7.7)	
	Middle	48,776(53.6)	17,165(18.9)	31,611(34.7)	
	Upper-middle	18,308(20.1)	6276(6.9)	12,032(13.2)	
	High-income	3756(4.1)	1441(1.6)	2315(2.5)	
Number of participating countries by continent: N (RR*)	Africa	America	Asia	Europe	Oceania
	48 (24.6%)	19 (9.7%)	44 (22.5%)	39 (20%)	4(2%)
No participation: N	6	16	4	5	10

*Response Rate

(35.40%) males]. Respondents were well represented by ages 21 to 30 years (37,577, 41.30%), urban areas (76,122, 83.60%), bachelor's degree (38,924, 42.70%), and median income (48,776, 53.60%). In this study, the income level was considered relative to the average income of each country.

Therefore, the majority of participants had an average income in their country. Out of 193 United Nations (UN) members (and 2 countries that are non-member observer states: the Holy See and the State of Palestine), 154 countries participated in this study. The global participation rate was reported

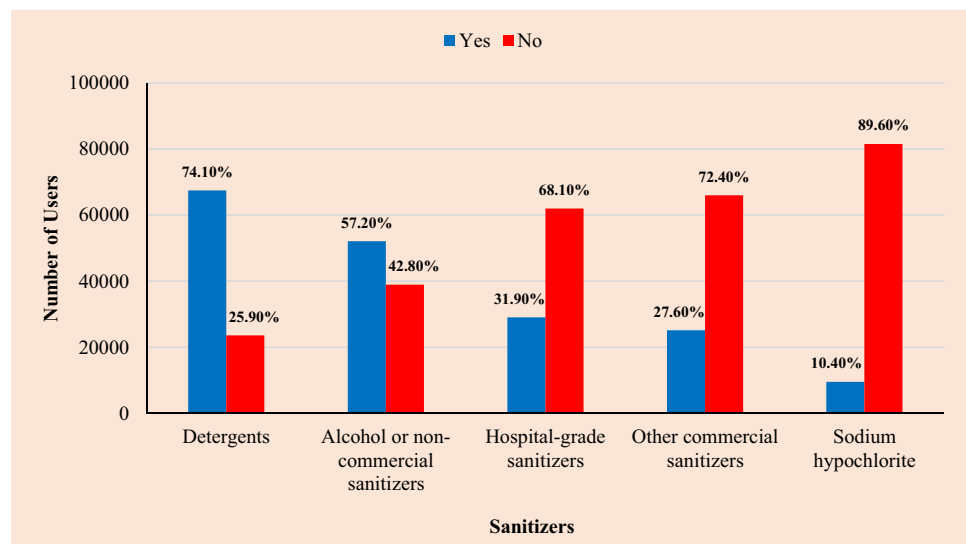
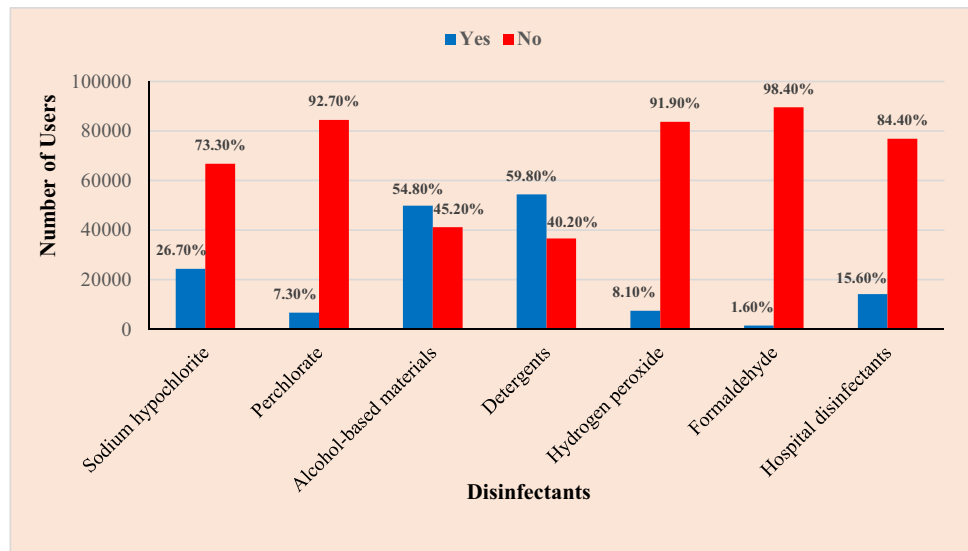
Fig. 1 Usage status of five groups of sanitizers

Fig. 2 Usage status of seven groups of disinfectants

to be 79%. 41 countries (21%) from different continents did not participate in the study. According to Table 1, the number of participating countries from each continent includes Africa (48), America (19), Asia (44), Europe (39), and Oceania (4) countries correctly completed the questionnaire.

Type and volume of sanitizers and disinfectants used

In the second part of the questionnaire, questions were asked about the type, volume, and number of times of daily use of 5 types of chemical compounds as sanitizers (Figure 1) and 7 types of substances as disinfectants (Figure 2). The status of the use of sanitizers and disinfectants is shown in Table 2 and Figures 1, 2, and 3. The usage status of the sanitizers for handwashing or other living surfaces is shown in Figure 1. Compared to other sanitizers, the highest use was detergents (soap and toilet liquid, dishwashing liquid) (67,445 users), and alcohol or non-commercial sanitizers (52,083 users). In contrast, chlorine compounds such as sodium hypochlorite

(9490 users) were used less often as sanitizers. Additionally, the status of seven groups of disinfectants, which are used for the disinfection of various high-touch surfaces such as door handles, tables, chairs, remotes, keys, elevator buttons, etc., was explored (Figure 2). In this group, in addition to detergents (54,445 users) and alcohol-based products (49,879 users), which were most used compared to other disinfectants, the use of sodium hypochlorite was reported as a high-consumptive disinfectant (24,296 users). In contrast, formaldehyde (1441 users) and per-chlorine (6605 users) had the lowest usage as a disinfectant.

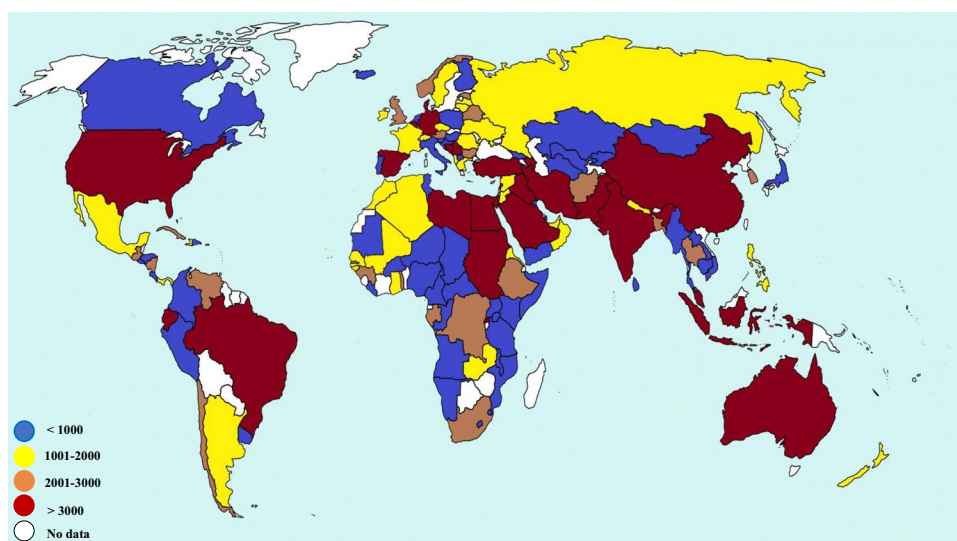
In terms of the frequency of daily use of sanitizers and disinfectants, the results showed that most participants tended to use sanitizers and disinfectants 1 to 3 times a day (29,778 users) and once a day (35,959 users), respectively. The volume of chemicals used was also one of the important factors in creating the scenarios of possible adverse effects and we found that most of the participants stated using the sanitizers and disinfectants at a volume of approximately 101–300 mL, and 0.5–1 L per month, respectively (Table 2).

Table 2 Usage status of sanitizers and disinfectants

	Frequency of daily use					Monthly usage volume (CC**)				
	Once a day	1–3/d	4–6/d	> 6/d	None	Low (≤100)	Average (101 to 300)	High (301 to 500)	Too much (≥500)	None
Sanitizers: N* (%)	11,069 (12.2)	29,778 (32.7)	27,407 (30.1)	21,608 (23.7)	1140 (1.3)	22,849 (25.1)	45,091 (49.5)	13,292 (14.6)	8572 (9.4)	1198 (1.3)
	Frequency of daily use					Monthly usage volume (L***)				
	Once a day	1–3/d	4–6/d	> 6/d	None	Low (≤0.5)	Average (0.5 to 1)	High (1.1 to 2)	Too much (>2)	None
Disinfectants: N (%)	35,959 (39.5)	34,436 (37.8)	11,158 (12.3)	5159 (5.7)	3990 (4.4)	27,727 (30.5)	44,686 (49.1)	10,783 (11.8)	4978 (5.5)	2816 (3.1)

*The users of sanitizers and disinfectants. **It is expressed in CC due to its use for living surfaces. ***It is expressed in liters due to its use for non-living surfaces

Fig. 3 Distribution of the use of sanitizers and disinfectants in different countries



The continental distribution of the inclination of users (individuals) to use sanitizers and disinfectants is shown in Figure 3. Four groups of countries were determined according to the sanitizers and disinfectant usage rate: countries with low usage (blue <1000), medium usage (yellow = 1001–2000), high usage (brown = 2001–3000), and countries that tend to consume too many sanitizers and disinfectants (red >3000). The number of countries that were less inclined to use sanitizers and disinfectants was in Africa, while the number of countries with the highest level of usage was in Asia. Similarly, the continental distribution shows that most countries with moderate usage of sanitizers and disinfectants were in continental Europe.

Adverse health outcomes of sanitizers and disinfectants

The distribution of the frequency of adverse events showed that the most common complaints reported by the participants were related to skin and respiratory system effects (Figure 4). The highest and lowest frequencies were related to skin dryness (65,680 cases) and neurological effects (headache, dizziness, and vomiting) (13,063 cases), respectively. Table 3 shows the possible adverse health outcomes as a result of the use of sanitizers and disinfectants based on the reports of the participants in this study. There was a significant relationship between the use of chlorine compounds such as sodium hypochlorite and per-chlorine with all the adverse effects ($p < 0.001$) (Table 3).

Skin effects

The use of detergents and alcohol or alcohol-based products resulted in a greater adverse effect on the skin than

other chemicals (Table 3). Among the skin effects, the most commonly reported adverse effect was skin dryness. 45,259 and 39,573 of the participants complained of dry skin due to the use of detergents and alcohol or alcohol-based materials, respectively. There was a significant relationship between itching and skin irritation with all chemicals (except other commercial sanitizers and hospital disinfectants) ($p < 0.001$). Unlike other chemicals, there was no significant relationship between skin scaly with alcohols, commercial sanitizers, and hydrogen peroxide ($p > 0.05$).

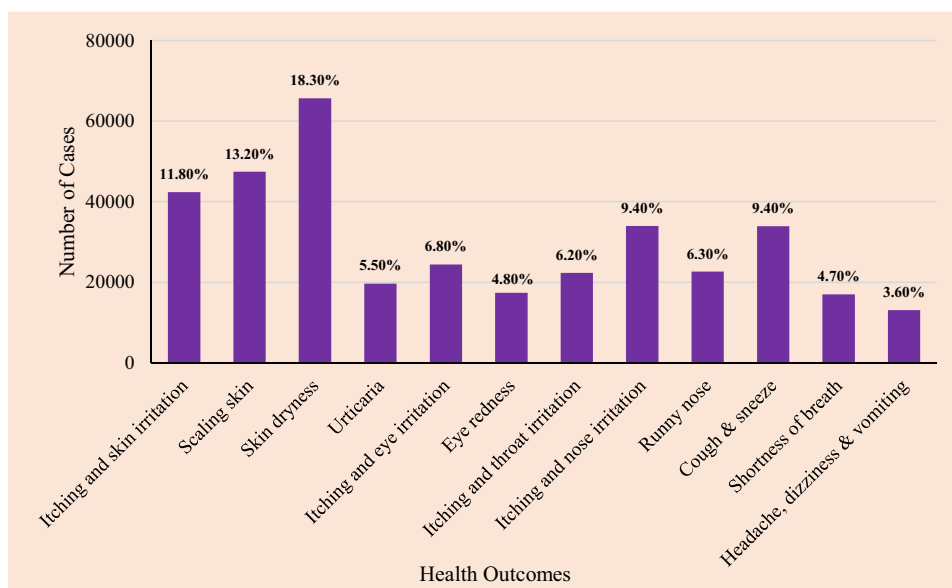
Ocular effects

The contribution of sodium hypochlorite in causing ocular effects was greater than other chemicals. Participants reported itching and ocular irritation (15,407 cases) and ocular redness (11,302 cases) after using sodium hypochlorite. The data show a significant relationship between itching and ocular irritation with all sanitizers and disinfectants (except detergents and alcohol or alcohol-based materials) ($p < 0.001$) (Table 3).

Throat effects

Participants reported itching and irritation of the throat after using alcohol or alcohol-based products (12,591 cases), hospital-grade sanitizers such as savlon (6671 cases), and other commercial sanitizers (6035 cases). Itching and irritation of the throat as one of the possible side effects of sanitizers and disinfectants was significantly associated with some chemicals such as chlorine compounds (sodium hypochlorite and per-chlorine), hospital disinfectants, hydrogen peroxide, formaldehyde ($p < 0.001$) (Table 3).

Fig. 4 The frequency distribution of 12 health outcomes studied



Respiratory system effects

Respiratory effects including itching and nose irritation (19,692 cases), runny nose (12,601 cases), and cough and sneezing (20,148 cases) were reported after using alcohol or alcohol-based products. There was a significant relationship between shortness of breath with all chemicals except detergents (all $p < 0.001$). In contrast, except for chlorine compounds, there was no significant relationship between cough, sneezing, and runny nose with the majority of sanitizers and disinfectants ($p > 0.05$) (Table 3).

Neurological effects

The present findings showed that less than eight percent of the participants had self-reported neurological effects including headache, dizziness, and vomiting after using sanitizers and disinfectants. In total, 7114 and 419 of participants complained of headache, dizziness, and vomiting after using alcohol (the most) and formaldehyde (the least), respectively. The results indicated that a statistically significant relationship was found between possible neurological problems due to the use of analyzed sanitizers and disinfectants (except detergents) (all $p < 0.001$) (Table 3).

Multivariable logistic regression analysis

After controlling for confounders (demographic characteristics), a multivariable logistic regression analysis was performed to determine the risk factors associated with adverse health outcomes (Table 4). The use of some sanitizers and

disinfectants was associated with skin adverse effects (e.g., Itching and skin irritation after using alcohol or alcohol-based materials: OR, 1.86; 95%CI, $p > 0.05$; or as a result of using sodium hypochlorite: OR, 1.43; 95%CI, $p < 0.001$). In contrast, the use of some other sanitizers and disinfectants was associated with a lower chance of itching and skin irritation (hospital disinfectants: OR, 0.91; 95%CI, $p < 0.001$). The use of Per-chlorine (OR, 1.47; 95%CI, $p < 0.001$), alcohol-based materials (OR, 1.98; 95%CI, $p < 0.001$), formaldehyde (OR, 1.40; 95%CI, $p < 0.001$) were associated with higher odds of skin dryness, scaling of the skin, skin urticaria respectively.

Itching and ocular irritation were reported after using per-chlorine: OR, 1.83; 95%CI, $p < 0.001$; and sodium hypochlorite: OR, 1.33; 95%CI, $p < 0.001$. Similarly, ocular redness was associated with the use of per-chlorine (OR, 1.77; 95%CI, $p < 0.001$), and hydrogen peroxide (OR, 1.49; 95%CI, $p < 0.001$).

The results showed that one of the important risk factors for throat-related effects is chlorine-based compounds. Per-chlorine resulted in double the risk for throat-related effects (OR, 2.00; 95%CI, $p < 0.001$), and sodium hypochlorite use is also a serious risk factor for itching and throat irritation (OR, 1.66; 95%CI, $p < 0.001$). Furthermore, the use of sodium hypochlorite (OR, 1.74; 95%CI, $p < 0.001$), and formaldehyde (OR, 1.56; 95%CI, $p < 0.001$) were accompanied by coughing and sneezing. Similarly, shortness of breath was associated with the use of sodium hypochlorite (OR, 1.78; 95%CI, $p < 0.001$), and per-chlorine (OR, 1.67; 95%CI, $p < 0.001$). There was a strong association between the use of formaldehyde and the occurrence of neurological effects (OR, 2.17; 95%CI, $p < 0.001$).

Table 3 Frequency table and the relationship between sanitizers/disinfectants and health outcomes (Chi-square test)

Type of chemical		Itching and skin irritation		Skin dryness		Hand scaling		Skin urticaria (Hives)	
		Yes N (%)	No N (%)	Yes N (%)	No N (%)	Yes N (%)	No N (%)	Yes N (%)	No N (%)
Detergents (Soap and toilet liquid, dish-washing liquid)	Yes	29,952(32.9)	30,996(34.0)	45,259(49.7)	15,688(17.2)	33,286(36.6)	27,662(30.4)	7037(7.7)	48,320(53.1)
	<i>P-value</i>	<0.001		<0.001		<0.001		<0.001	
Alcohol or alcohol-based materials	Yes	24,786(27.2)	27,300(30.0)	39,573(43.5)	12,513(13.7)	27,979(30.7)	24,107(26.5)	10,614(11.7)	41,472(45.5)
	<i>P-value</i>	<0.001		<0.001		<0.025		<0.001	
Sodium hypochlorite (bleach)	Yes	19,450(21.4)	7443(8.2)	33,453(36.7)	3440(3.8)	29,954(32.9)	6940(7.6)	4364(4.8)	12,529(13.8)
	<i>P-value</i>	<0.001		<0.001		<0.001		<0.001	
Hospital-grade sanitizers (savlon)	Yes	14,322(15.7)	14,698(16.1)	21,417(23.5)	7603(8.3)	15,369(16.9)	13,651(15.0)	6134(6.7)	22,886(25.1)
	<i>P-value</i>	<0.001		<0.001		<0.001		0.022	
Other commercial sanitizers	Yes	11,719(12.9)	13,372(14.7)	17,880(19.6)	7211(7.9)	13,082(14.4)	12,009(13.2)	5018(5.5)	20,073(22.0)
	<i>P-value</i>	0.592		<0.001		0.847		<0.001	
Hospital disinfectants	Yes	6501(7.1)	7685(8.4)	10,447(11.5)	3739(4.1)	6943(7.6)	7243(8.0)	3432(3.8)	10,754(11.8)
	<i>P-value</i>	0.057		<0.001		<0.001		<0.001	
Per-chlorine	Yes	4097(4.5)	2511(2.8)	5234(5.7)	1374(1.5)	4581(5.0)	2027(2.2)	1918(2.1)	4690(5.2)
	<i>P-value</i>	<0.001		<0.001		<0.001		<0.001	
Hydrogen peroxide	Yes	3788(4.2)	3592(3.9)	5387(5.9)	1993(2.2)	3925(4.3)	3455(3.8)	1872(2.1)	5508(6.0)
	<i>P-value</i>	<0.001		0.088		0.049		<0.001	
Formaldehyde	Yes	768(0.8)	676(0.7)	1000(1.1)	444(0.5)	923(1.0)	521(0.6)	436(0.5)	1008(1.1)
	<i>P-value</i>	<0.001		0.015		<0.001		<0.001	
Type of chemical		Itching and eye irritation		Eye redness		Itching and throat irritation		Itching and nose irritation	
		Yes N (%)	No N (%)	Yes N (%)	No N (%)	Yes N (%)	No N (%)	Yes N (%)	No N (%)
Detergents (soap and toilet liquid, dish-washing liquid)	Yes	6294(6.9)	44,654(49.0)	11,255(12.3)	49,580(54.5)	964(1)	45,754(50.2)	12,976(14.3)	37,971(41.7)
	<i>P-value</i>	0.039		<0.001		<0.001		0.002	
Alcohol or non-commercial alcohol-based sanitizers	Yes	14,108(15.5)	10,309(11.3)	9289(10.2)	8077(8.9)	12,591(13.8)	39,495(43.4)	19,692(21.6)	32,394(35.6)
	<i>P-value</i>	0.034		<0.001		<0.001		0.068	
Sodium hypochlorite (bleach)	Yes	15,407(16.9)	11,487(12.6)	11,302(12.4)	12,592(13.8)	5502(6.0)	11,391(12.5)	17,551(19.3)	9342(10.3)
	<i>P-value</i>	<0.001		<0.001		<0.001		<0.001	
Hospital-grade sanitizers	Yes	7180(7.9)	21,840(24.0)	5450(6.0)	23,570(25.9)	6671(7.3)	22,349(24.5)	10,359(11.4)	18,661(20.5)
	<i>P-value</i>	<0.001		0.126		0.321		0.210	
Other commercial sanitizers	Yes	6440(7.1)	18,651(20.5)	4482(4.9)	20,609(22.6)	6035(6.6)	19,056(20.9)	8911(9.8)	16,180(17.8)
	<i>P-value</i>	<0.001		<0.001		<0.001		0.055	
Hospital disinfectants	Yes	3310(3.6)	10,876(11.9)	2658(2.9)	11,528(12.7)	2978(3.3)	11,208(12.3)	4530(5.0)	9656(10.6)
	<i>P-value</i>	<0.001		0.274		<0.001		<0.001	
Per-chlorine	Yes	2614(2.9)	3994(4.4)	1922(2.1)	4686(5.1)	2624(2.9)	3984(4.4)	3484(3.8)	3124(3.4)
	<i>P-value</i>	<0.001		<0.001		<0.001		<0.001	

Table 3 (Continued)

Hydrogen peroxide	Yes	2084(2.3)	5296(5.8)	1750(1.9)	5630(6.2)	2049(2.3)	5331(5.9)	2579(2.8)	4801(5.3)
	<i>P</i> -value	<0.001		<0.001		<0.001		0.332	
Formaldehyde	Yes	525(0.6)	919(1.0)	410(0.5)	1034(1.1)	482(0.5)	962(1.1)	715(0.8)	729(0.8)
	<i>P</i> -value	<0.001		<0.001		<0.001		<0.001	
Type of chemical	Runny nose								
	Yes		No	Yes	No	Yes	No	Yes	No
	N (%)		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Detergents (Soap and toilet liquid, dish-washing liquid)	Yes	3296(3.6)	45,653(50.1)	5033(5.5)	36,868(40.5)	6248(6.9)	49,700(54.6)	4213(4.6)	52,335(57.5)
	<i>P</i> -value	0.002				0.065		0.118	
Alcohol or alcohol-based materials	Yes	12,601(13.8)	39,485(43.4)	20,148(22.1)	13,773(15.1)	9206(10.1)	42,880(47.1)	7114(7.8)	44,972(49.4)
	<i>P</i> -value	0.068				<0.001		<0.001	
Sodium hypochlorite (bleach)	Yes	5753(6.3)	11,141(12.2)	7833(8.6)	9061(10.0)	11,738(12.9)	13,156(14.4)	2929(3.2)	13,965(15.3)
	<i>P</i> -value	<0.001				<0.001		<0.001	
Hospital-grade sanitizers	Yes	6473(7.1)	22,547(24.8)	10,172(11.2)	18,848(20.7)	5091(5.6)	23,929(26.3)	3682(4.0)	25,338(27.8)
	<i>P</i> -value	0.210				<0.001		<0.001	
Other commercial sanitizers	Yes	5845(6.4)	19,246(21.1)	8857(9.7)	16,234(17.8)	4223(4.6)	20,868(22.9)	3368(3.7)	21,723(23.9)
	<i>P</i> -value	0.055				<0.001		<0.001	
Hospital disinfectants	Yes	2784(3.1)	11,402(12.5)	4460(4.9)	9726(10.7)	2164(2.4)	12,022(13.2)	2005(2.2)	12,181(13.4)
	<i>P</i> -value	<0.001				<0.001		<0.001	
Per-chlorine	Yes	2594(2.8)	4014(4.4)	3396(3.7)	3212(3.5)	1881(2.1)	4727(5.2)	1425(1.6)	5183(5.7)
	<i>P</i> -value	<0.001				<0.001		<0.001	
Hydrogen peroxide	Yes	7380(8.1)	5582(6.1)	2677(2.9)	4703(5.2)	1593(1.7)	5787(6.4)	1254(1.4)	6126(6.7)
	<i>P</i> -value	0.332				<0.001		<0.001	
Formaldehyde	Yes	537(0.6)	907(1.0)	708(0.8)	736(0.8)	428(0.5)	1016(1.1)	419(0.5)	1025(1.1)
	<i>P</i> -value	<0.001				<0.001		<0.001	

Table 4 Risk factors for health effects by Multivariable Logistic Regression Analysis

Type of chemical	Itching and skin irritation			Skin dryness			Skin scaling			Skin urticaria (Hives)		
	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P
Detergents (Soap and toilet liquid, dish-washing liquid)	1.15	1.09–1.21	<0.001	1.06	1.02–1.10	<0.001	1.15	1.11–1.19	<0.001	0.94	0.90–0.97	<0.001
Alcohol or alcohol-based materials	1.86	1.77–1.96	0.020	1.30	1.26–1.34	<0.001	1.98	1.87–2.09	<0.001	0.86	0.83–0.89	<0.001
Sodium hypochlorite (bleach)	1.43	1.39–1.48	<0.001	1.40	1.35–1.46	<0.001	1.30	1.24–1.37	<0.001	0.90	0.87–0.93	<0.001
Hospital-grade sanitizers	1.08	1.05–1.12	<0.001	0.82	0.79–0.93	<0.001	1.01	0.98–1.04	0.394	0.86	0.83–0.89	<0.001
Other commercial sanitizers	0.90	0.87–0.93	<0.001	0.86	0.83–0.89	<0.001	0.95	0.92–0.98	0.005	0.82	0.79–0.85	<0.001
Hospital disinfectants	0.91	0.88–0.95	<0.001	1.10	1.06–1.15	<0.001	0.84	0.81–0.87	<0.001	1.26	1.21–1.32	<0.001
Per-chlorine	0.96	0.94–0.99	<0.001	1.47	1.38–1.56	<0.001	1.37	1.29–1.45	<0.001	0.95	0.90–1.01	0.125
Hydrogen peroxide	1.15	1.09–1.21	<0.001	0.95	0.90–1.01	0.125	0.96	0.91–1.01	0.136	1.37	1.29–1.45	<0.001
Formaldehyde	1.20	1.07–1.34	<0.001	0.85	0.76–0.96	0.011	1.46	1.31–1.64	<0.001	1.40	1.24–1.57	<0.001
Type of chemical	Itching and Eye Irritation			Eye Redness			Itching and Throat Irritation			Itching and Nose Irritation		
	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P
Detergents (Soap and toilet liquid, dish-washing liquid)	0.95	0.92–0.98	<0.001	0.85	0.82–0.88	<0.001	0.69	0.62–0.76	0.063	1.21	1.17–1.24	<0.001
Alcohol or alcohol-based materials	1.11	1.07–1.15	0.002	1.05	1.01–1.08	<0.001	0.97	0.93–1.00	0.053	1.07	1.04–1.11	<0.001
Sodium hypochlorite (bleach)	1.33	1.27–1.40	<0.001	1.65	1.58–1.71	<0.001	1.66	1.58–1.74	<0.001	1.48	1.41–1.55	<0.001
Hospital-grade sanitizers	0.83	0.80–0.86	<0.001	0.90	0.86–0.93	<0.001	0.84	0.81–0.87	<0.001	0.87	0.84–0.89	<0.001
Other commercial sanitizers	0.89	0.86–0.92	<0.001	0.81	0.77–0.84	<0.001	0.89	0.86–0.93	<0.001	0.85	0.82–0.88	<0.001
Hospital disinfectants	0.90	0.86–0.94	<0.001	-	-	-	0.83	0.79–0.87	<0.001	0.82	0.79–0.86	<0.001
Per-chlorine	1.83	1.74–1.93	<0.001	1.77	1.68–1.88	<0.001	2.00	1.90–2.11	<0.001	1.87	1.78–1.97	<0.001
Hydrogen peroxide	1.15	1.09–1.22	<0.001	1.49	1.40–1.58	<0.001	1.19	1.13–1.26	<0.001	0.92	0.87–0.97	0.003
Formaldehyde	1.40	1.26–1.57	<0.001	1.34	1.19–1.52	<0.001	1.29	1.15–1.45	<0.001	1.56	1.40–1.73	<0.001
Type of chemical	Runny nose			Cough and Sneeze			Shortness of breath			Headaches, Dizziness, and Vomiting		
	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P	Adjusted OR	CI (95%)	P

Table 4 (continued)

Detergents (Soap and toilet liquid, dish-washing liquid)	0.93	0.90–0.97	<0.001	0.67	0.61–0.78	<0.001	0.94	0.90–0.98	0.004	0.95	0.92–0.99	0.019
Alcohol or alcohol-based materials	0.76	0.73–0.79	<0.001	1.05	1.02–1.08	0.005	0.91	0.87–0.94	<0.001	1.06	1.02–1.10	0.002
Sodium hypochlorite (bleach)	1.76	1.6–1.8	<0.001	1.74	1.65–1.83	<0.001	1.78	1.68–1.88	<0.001	1.32	1.27–1.38	<0.001
Hospital-grade sanitizers	0.76	0.73–0.79	<0.001	0.83	0.80–0.85	<0.001	0.77	0.74–0.80	<0.001	0.90	0.86–0.93	<0.001
Other commercial sanitizers	0.82	0.79–0.85	<0.001	0.83	0.81–0.86	<0.001	0.84	0.81–0.88	<0.001	0.81	0.78–0.84	<0.001
Hospital disinfectants	0.76	0.73–0.80	<0.001	0.81	0.77–0.84	<0.001	1.10	1.04–1.15	<0.001	0.80	0.76–0.84	<0.001
Per-chlorine	1.91	1.81–2.02	<0.001	1.47	1.42–1.52	<0.001	1.67	1.56–1.77	<0.001	1.72	1.62–1.81	<0.001
Hydrogen peroxide	1.06	1.00–1.13	0.031	0.97	0.92–1.02	<0.001	1.30	1.22–1.39	<0.001	1.36	1.28–1.44	<0.001
Formaldehyde	1.59	1.42–1.78	<0.001	1.56	1.40–1.73	<0.001	1.15	1.09–1.22	<0.001	2.17	1.92–2.44	<0.001

Adjusted for age, sex, educational level, occupational status, place of residence (rural and city), and income level

Discussion

Regarding the use of sanitizers and disinfectants in different continents, it was observed that in African countries, due to low-income levels, and lack of accessibility the tendency to use disinfectants was lower than in other continents. In contrast, in some less-resourced countries, such as Iran, and more-resourced countries, such as China, the USA, the UK, Germany, and Australia, etc., there was a greater tendency to use disinfectants. Adequate income levels, adequate education, and information, easy access to the types of sanitizers and disinfectants, and strict controlling measures by the governments have been effective in increasing the use of these chemicals (Becher et al., 2021; Bu et al., 2020; Tran et al., 2020; Unruh et al., 2022; Xu et al., 2020). Although our claim regarding some countries such as Venezuela, Iraq, Afghanistan, etc. was not correct. Contrary to the economic crisis prevailing in these countries, the use of sanitizers and disinfectants was high.

In addition to this more attention and the fear of contracting the disease, sometimes leads to the excessive usage of sanitizers and disinfectants, which leads to the occurrence of adverse effects due to the toxic nature of these chemicals on the population; finally, the body's resistance to other infectious agents may decrease (Tachikawa, 2020; Vogel, 2011). On the other hand, the denial of the existential nature of the COVID-19 disease by people from different countries (Afolabi and Ilesanmi, 2021; Buguzi, 2021; Cabral et al., 2021; Thagard, 2021) can be one of the main reasons for not tending to use sanitizers and disinfectants as part of health protocols. We found that the disinfectants with the highest rate of causing different adverse health effects are chlorine compounds (sodium hypochlorite and per-chlorine). One of the reasons for this finding could be the widespread use of these compounds as bleaches, cleansers, and vegetable washes, for washing different surfaces, water disinfection as well as easy access and affordability. In addition to the inherent effects of using chemicals as sanitizers and disinfectants, there are other reasons such as misuse (mixing several chemicals without following the instructions), excessive use, and counterfeit and unauthorized products that can cause side effects (Alhourri et al., 2020; Cook and Brooke, 2021). However, some disinfectants (e.g., detergents) may not have serious adverse effects on human health, but prolonged exposure and overuse of any chemical increase their harmful potential (Baldeo et al., 2022). Similar studies have shown that most disinfectants, such as alcohols and proxygene compounds, can be considered potential irritants or skin allergens (Goh et al., 2021; Lachenmeier, 2008; Murphy and Friedman, 2019). The US centers for disease control and prevention (CDC) reported an increase in calls to the center because of overuse and frequent exposure to cleaning

chemicals during the Covid-19 pandemic (CDC, 2020; Rosenman et al., 2021).

Various reports have claimed that long-term use of surfactants causes dryness and roughness of the skin (Goh et al., 2021; Paudel et al., 2022; Shibuya et al., 2022). Similarly, alcohol-based substances despite their low permeability to the skin had the most skin effects as a result of prolonged contact and regular and continuous use. Similar studies have reported increased exposure and frequency of alcohol use as a cause of skin irritation or dermatitis (Boutchoorn et al., 2011; Ghafoor et al., 2021; Lachenmeier, 2008). Unlike sanitizers and other disinfectants, alcohols were more effective in causing skin urticaria. In one study, skin urticaria was reported as a result of alcohol use (such as isopropanol) due to the combination of these alcohols with some solvents and organic matter (Berardi et al., 2020; Goh and Ahmed, 2020; Pecquet et al., 1992). The results obtained in this study regarding skin effects were in accordance with some scientific texts and similar studies (Bito et al., 2010; Chan and Maibach, 2008; Europe, 2017; Murphy and Friedman, 2019). The results of the multivariate regression analysis showed that detergents, alcohols or alcohol-based substances, and chlorine compounds have a higher potential of causing skin effects compared to other sanitizers and disinfectants.

Ocular effects (itching and irritation and eye redness) due to the use of sanitizers and disinfectants were less common than other effects. However, in terms of frequency, detergents and alcohol accounted for the largest share of ocular side effects. The results of some studies confirm our findings that itching and eye irritation are a result of the use of alcohol as a sanitizer/disinfectant (Ghafoor et al., 2021). Statistical results showed that among the chemicals studied, chlorine compounds had a higher chance of causing ocular effects compared to other disinfectants. This is probably due to the wide range of applications of chlorine compounds for different purposes as well as their ability to be mixed with other solvents. Studies have shown that the use of chlorine-based compounds in the form of sprays to disinfect surfaces will cause itching and eye irritation (Ghafoor et al., 2021; Schyllert et al., 2016; WHO, 2020). Since people used several types of chemicals separately or mixed to wash hands, face, and feet or to disinfect different surfaces, improper mixing of chemicals may release toxic gases and vapors that can affect the respiratory system. Studies have shown that mixing bleach with acidic cleaning agents leads to the release of highly irritating gases (PHE, 2015; Racioppi et al., 1994). Rosenman et al. claimed that not following hygienic instructions on how to use or mix cleansing products with other chemicals such as acid would create the conditions for chemical pneumonia or pulmonary edema (Rosenman et al., 2021). Our findings showed that chlorine compounds (sodium hypochlorite and per-chlorine) were involved in

causing all effects related to the respiratory system. This claim was consistent with a list approved by the US Environmental Protection Agency (Alimohamadi et al., 2022b) that sodium hypochlorite is an irritant and allergen for the respiratory system (EPA, 2020). The results of multivariate regression analysis showed that formaldehyde had an immensely significant chance of causing neurological effects compared to other sanitizers and disinfectants. Formaldehyde, as a carcinogen by OSHA (Tarka et al., 2016), has an unpleasant odor and is an irritant that can cause many adverse effects on human health (Ghafoor et al., 2021).

Strengths and limitations

The present study holds significant value due to its comprehensive nature, covering 154 out of 192 United Nations member countries, indicating a truly global scope. The primary objective of this study was to achieve optimal participation across diverse segments of the general population. Regrettably, certain subgroups, namely villagers, individuals above the age of 60, non-academic individuals, and those employed in blue-collar occupations such as construction, manufacturing, and maintenance, exhibited lower levels of participation. This constraint constitutes a further limitation of the study. The main limitations of this study were the non-participation of individuals for personal reasons or lack of access to the internet, the drop-out of some countries (41 countries), and background effects such as exposure to various pollutants causing effects such as inflammation and respiratory effects, etc. (Hashemi et al., 2022a).

Conclusion

Our findings could serve as a useful source of information in reducing concerns related to the adverse health effects of sanitizers and disinfectant use through education and information by governments and health organizations during viral epidemics. Furthermore, the present results can be helpful for safety and health organizations overseeing the production of chemicals in updating instructions on how to use chemicals, as well as replacing low-risk, low-dose, high-impact chemicals in the production process if possible.

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Material preparation by Fallah Hashemi and Mohammad Hoseini, and data analysis by Lori Hoepner and Sima Afrashteh were performed. The first draft of the manuscript was written by Fallah Hashemi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability There is no data to access online.

Declarations

Ethics approval The study sampling protocol was approved by the Ethics Committee of the Shiraz University of Medical Science (IR.SUMS.REC.1400.023).

Consent to participate All the people who participated in this study through an electronic questionnaire; Before answering the questions, they should have chosen the option of informed consent to participate in this research. It is necessary to explain that without choosing the option of informed consent, the participants were not able to enter the other sections of the questionnaire.

Consent for publication All authors declare their consent to publish this article.

Competing interests The authors declare no competing interests.

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