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Risk assessment of heavy metals consumption through onion on human health in Iran

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ABSTRACT

Considering the importance of onions consumption in the household diet, controlling of heavy elements' concentration in foodstuffs is important to ensure the safety of an individual's health. This study aimed to evaluate the risk of heavy metals through onion consumption on human health. In this cross-sectional experimental study, 22 onion samples with varieties red, yellow, and white in the two autumn and winter seasons in 2020 were randomly collected from the different provinces of Kurdistan, Hamedan, and Kermanshah. The concentrations of heavy metals were evaluated with an atomic absorption spectrometer. The risks of human health were evaluated by the hazard quotient (HQ) and the obtained results were analyzed with one-way ANOVA and one sample *t*-test. The obtained findings demonstrated that all collected samples contained heavy metals. For example, the cadmium (Cd) concentration in onion samples in the province of West Azerbaijan, Kurdistan, Hormozgan, Isfahan, and Zanjan was 526.49, 274.49, 69.77, 67.39, 65.69 μg kg^{-1}, respectively. While the standard specified in Iran for the concentration of Cd in onions is 50 μg kg^{-1}. However, the rate of lead (Pb) contamination in samples collected from Isfahan, Hormozgan, Zanjan Khuzestan, Tehran (Varamin) was 296.50, 266.71, 261.49, 215.64, 106.19 μg kg^{-1}, respectively, which less than maximum allowable limit recommended by WHO-FAO (300 μg kg^{-1}). The HQ for non-cancerous diseases for Cd and Pb were 8.6×10^{-2} and 1.6×10^{-1}, respectively, and the probability of carcinogenic risk for Pb (8.1×10^{-4}) was at the level of acceptable. There is no concern about the non-carcinogenic diseases and carcinogenic risk of consuming heavy metals in onion. Therefore, for optimal management and prevention of further pollution, it is recommended to study the origin and determine the amounts of heavy metals for their potential contamination of foodstuffs from the region's soil, water, and dust.

Introduction

Environmental pollutions, such as contamination with heavy metals, can affect the quality and safety of vegetables and herbs, known to be the most widely used plants in daily life (Singh & Kumar, 2006). Onion (Allium cepa) is a widely used vegetable in the world, a monocotyledon plant belonging to *Liliaceae* family (Mobli & Aslani, 2018), whose native and exotic breed genotypes are cultivated annually in Iran mainly (Elhami et al., 2021). The research of onion epidemiology shows that the onion's cultivation areas in the world and Iran are 3451941, 57112 ha, respectively, which is in the second place following the tomato (Ansari, 2007). Onion is grown in most province in Iran and are usually named after the city in which they are harvested. such as Azarshahar onion, Shahdad onion, Ramhormoz onion, and Bardseer onion. One of the most famous onions is Azarshahr red onion, which is mostly grown in northern Iran, East Azerbaijan province, and provides most of the onions consumed in Iran in autumn and winter (Ansari, 2007).

Onion consumption per capita reached 26.5 kg in 2018 in Iran and compared to Iran's main peers, onion consumption per capita in Iraq, Pakistan and Turkmenistan are 9.69, 8.74, and 14.9 kg respectively (Library, 2018). People worldwide use it as a spice to improve the taste and smell of food. Also, onions have medicational features such as anti-

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cancer (Block, 1985), antimicrobial (Griffiths et al., 2002), antiviral (Wu et al., 2005), antifungal (Lun et al., 1994), and also extracts and essential oils of these plants are effective in treating cardiovascular diseases (Rahman & Lowe, 2006). One of the primary health concerns in Iran is food safety as reports of increasing contamination of food with heavy metals are increasing (Fakhri et al., 2018b; Shokri et al., 2021). The high concentrations of heavy metals in the food chain have detrimental metabolic and physiological effects on living organisms. The trace metals could be categorized as toxic metals (arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), and nickel (Ni)), probably essential metals (vanadium (V)), and essential metals (copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), selenium (Se), and cobalt (Co)) (Adel et al., 2016). Though, in the case of exposure to a high concentration of the two groups mentioned, it can cause in toxic effects (Ghasemidehkordi et al., 2018). Metals such as Hg, Sn, Pb, As, and Cd cause several harms for human health even in little (Ghasemidehkordi et al., 2018, Ru et al., 2013). The toxic effects of heavy metals on the ecosystem and human health are well registered. Enhancing evidence has exposed that heavy metals' toxicity interacts with the human body with different mechanisms such as interference with essential metals, oxidative stress, and interplay with cellular macromolecules (Palpandi & Kesavan, 2012). Moreover, the heavy metals as non-biodegradable and highly bioaccumulative compounds can endanger the health of humans and animals through consumption by the food products (Fakhri et al., 2018a), owing to their mutagenic, teratogenic, and carcinogenic effects (Lawley et al., 2012; Mohammadi et al., 2014). In this regard, heavy metal also represents a worldwide issue in agricultural products such as fruits, vegetables, and cereals (Fathabad et al., 2018). One of the most important methods for heavy metal entrance to the food chain is their absorption from contaminated fields via plants, especially agricultural products (Muchuweti et al., 2006).

The concentration of heavy metals in the vegetables is directly dependent on their concentrations in the soil (Esmaeili et al., 2021; Sun et al., 2013). In this regard, the primary sources of Pb and Cd in the soil are related to atmospheric particulate deposition, municipal and industrial solid waste, untreated wastewater, fertilizers, and pesticides (Alloway, 2013).

Fallowing to the World Health Organization (WHO) and FAO standards, the tolerable weekly amount of Cd, and Pb are 490, 1750 μg per person, respectively (Ateş et al., 2015, Barkhordar, 2005; Joint, 1991). Also, the permissible values of Cd and Pb in vegetables are 0.2 and 0.3 mg/kg, respectively (Petursdottir et al., 2015).

According to reports in the study by Miri et al., the concentration of heavy metals in vegetables (lettuce, leeks, coriander, parsley) was higher than WHO and FAO standards, which could be related to soil or water pollution used to grow vegetables (Miri et al., 2016).

Abdullah et al showed the relative abundance of the trace metals in both the tomatoes and onions samples analyzed followed the sequence Pb > Cr > Cd. The trace metals values in both the exposed and controlled samples are higher than the FAO, WHO/EU, and FAO/WHO allowed the limit (Abdullahi et al., 2007). Therefore, the Heavy metal concentration of vegetables cannot be underestimated as these foodstuffs are important components of the human diet (Commission, 2001). It may be present either as a deposit on the surface of vegetables (Abulude, 2005) or may be taken up by the crop roots and incorporated into the edible part of plant tissues. Risk assessment is a clear way to facilitate decisions about hazardous substances in food. Li et al., investigated this issue under the title HQ (Li et al., 2010).

Considering the importance of consuming onions in Iran and the risk of heavy metals contamination in onion samples, increases the possibility of foodborne diseases, as well as the scarce data in this regard in Iran. Therefore, the current study was performed to risk assessment of heavy metals consumption through onion on human health in Iran.

Materials and methods

Sample collection

In the study, 22 samples of onion with varieties of white, red, and yellow in the two seasons of autumn and winter were collected from various provinces in Hamedan, Kurdistan, Kermanshah in 2020–2021. Onion was planted in different provinces Zanjan, Tabriz, Isfahan, Khuzestan, Kermanshah, Tehran (Varamin), Hormozgan, Kurdistan, and West Azerbaijan (Fig. 1). Then, the samples were transferred to the Food and Drug laboratory under sterile conditions and kept in a refrigerator at 4 °C until testing time.

Onion samples were washed, sliced, and dried for 48 hours in the oven at 105° C to maintain a stable weight (Din et al., 2013). Then, 0.5 g of the milled samples were weighed and poured into a China dish and placed in a furnace at 550°. The sample was ashed for about 5 h until a grey or white ash residue was obtained (Bhatnagar & Awasthi, 2000; Khan et al., 2008). The contents of the china dish were cooled to 25° C in desiccators and 5 mL of 2 M $HNO3$ solution was added into the China dish and when necessary, the mixture was heated to dissolve its content. The resulting solution was carefully transferred to a volumetric flask and finally, reached 100 mL using deionized water. Next, the measurements of Cd and Pb metals in onion samples were performed with an atomic absorption spectrometer (240 Varian) at specific wavelengths for each metal and the corresponding lamp (Cd at 228.8 nm and Pb at 217 nm) (Akan et al., 2013; Baird et al., 2017).

Non-carcinogenic diseases risk index

To evaluate the hazard of people being diagnosed with non-cancerous diseases was used, the following equation that reported by the USEPA (1992).

$$\mathrm{EDI} = (\mathrm{CF} \times \mathrm{IR} \times \mathrm{EF} \times \mathrm{ED})/(\mathrm{BW} \times \mathrm{AT})$$

EDI is the approximation of daily intake) mg $kg^{-1}day^{-1}$(; CF, the concentration of heavy metals in various foods (mg kg^{-1}); IR; ingestion rate daily (g day^{-1}), EF, exposure frequency (day $year^{-1}$); ED, exposure duration (years); BW, bodyweight (70 kg); AT; (EF × ED) average time exposure, RfD; Reference dose.

$$\mathrm{HQ} = \mathrm{EDI}\left(\mathrm{mgkg}^{-1}\mathrm{day}^{-1}\right)/\mathrm{RfD}\left(\mathrm{mgkg\ day}^{-1}\right) \quad (1)$$

When the non-cancer hazard index (HI) reaches one, it indicates a high hazard of non-cancerous diseases (Fallah et al., 2020).

$$\mathrm{HI} = \sum \mathrm{HQ}$$

Carcinogenic diseases risk index

The factor of additional risk appraisal for cancer incidence in life is an index for the carcinogenicity of the received toxin, and if it is measured low than one million, it will show insignificant conditions for the toxicity of the received toxin. Though, the measurement of numbers advanced than $\frac{1}{10000}$ of this index displays that this risk cannot be ignored and must be investigated more accurately and sensitively. The level of acceptable cancer risk is considered within the range of 10^{-6} to 10^{-4} (Aendo et al., 2019).

$$\text{Excess Lifetime Cancer Risk} = \mathrm{EDI} \times \text{Slope Factor} \quad (2)$$

Indicating oral cancer slope factor for Pb (0.0085 mg/kg/day) (USEPA, 2012).

Statistical analyses

The analysis of obtained results was applied the SPSS software

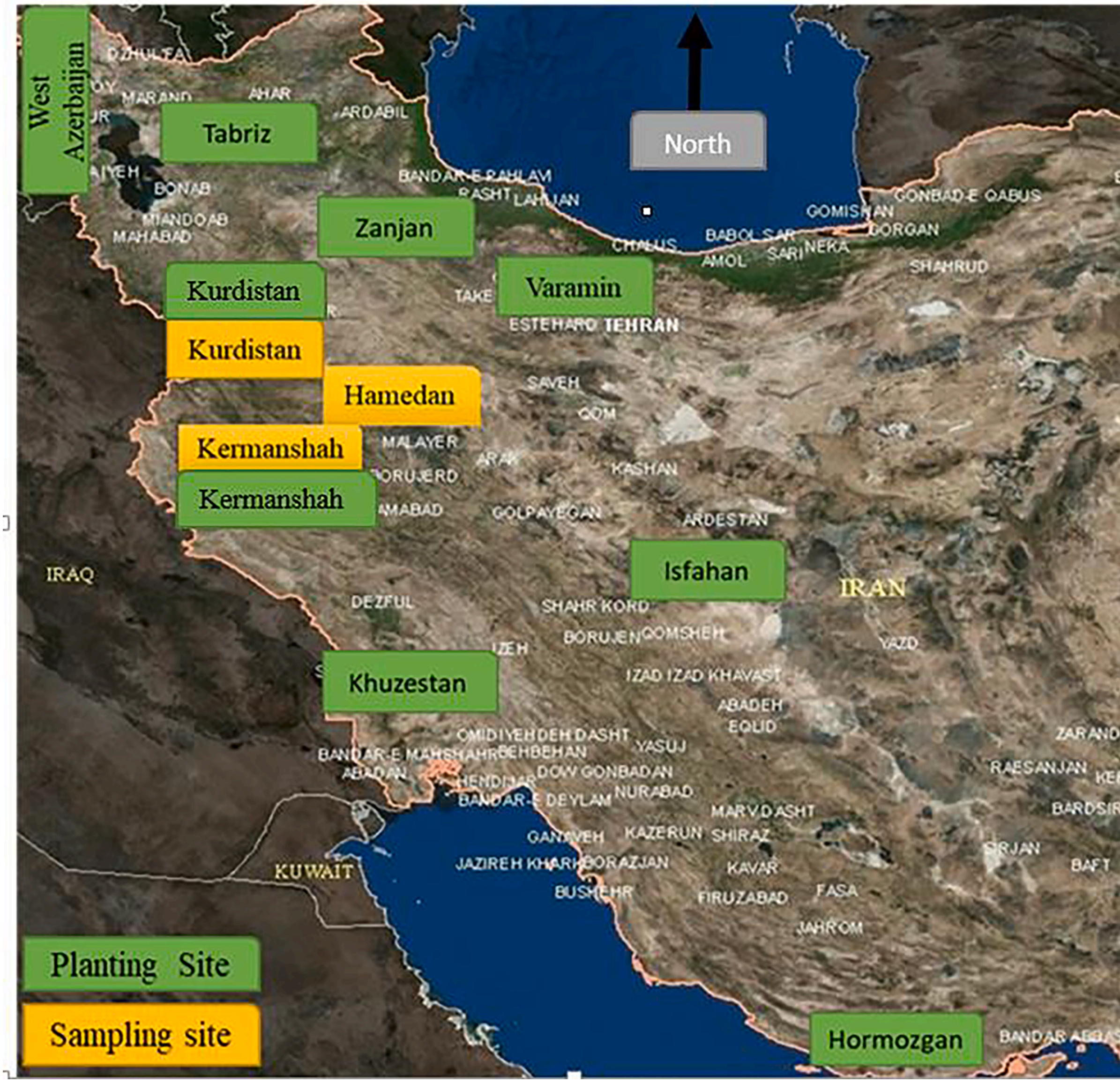

Fig. 1. Onion planting and sampling areas.

version 20, and data were reported as average, standard deviation, and 95% confidence interval. To compare the average concentration of heavy metals in onions, one-way ANOVA and one sample T-test were performed at a significant level of 0.05. Finally, the obtained numbers were compared with the standard.

Results

All samples were detectable in terms of heavy metals level. The Cd concentration range in cultivars of onions in province of West Azerbaijan, Kurdistan, Hormozgan, Isfahan, and Zanjan was 526.49 > 274.49 > 69.77 > 67.39 > 65.69 μg kg^{-1} advanced than the tolerable level measured with the national standard of Iran (50 μg kg^{-1}) respectively, and Cd content in all onion samples in Kurdistan and West Azerbaijan provinces (529.49 and 274.49 μg kg^{-1}, respectively) was 5 and 2 times higher than the recommended amount by WHO/FAO (100 μg kg^{-1}), respectively (Commission, 1995; Joint et al., 2001). The ratio concentration of Pb in onion samples in Isfahan, Hormozgan, Zanjan Khuzestan, Tehran (Varamin) province was 296.50 > 266.71 > 261.49 > 215.64 > 106.19 μg kg^{-1} respectively higher than the range tolerable by the National Standard Organization of Iran (100 μg kg^{-1}), but the level of Pb less than the maximum permissible limit set by WHO/FAO (300 μg kg^{-1}) (Table 1).

Based on one-way ANOVA test considering the probability of error of the first type ($\alpha = 0.05$), there was no major difference amongst the

Table 1
Content of heavy metals (μg kg^{-1}) in samples onion.

Locality	Planting Site	Cd Mean ± S.D	Pb Mean ± S.D
1	Zanjan	65.69 ± 66.21	261.49 ± 175.52
2	Tabriz	34.58 ± 46.72	87.19 ± 105.87
3	Isfahan	67.39 ± 22	296.50 ± 35
4	Khuzestan	39 ± 23	215.64 ± 41
5	Kermanshah	18 ± 0.75	71 ± 20
6	Tehran (Varamin)	0.60 ± 0.03	106.19 ± 10.7
7	Hormozgan	69.77 ± 0.05	266.71 ± 35
8	Kurdistan	274.49 ± 32	53.44 ± 32
9	West Azerbaijan	526.49 ± 41	67.63 ± 11
10	LOD*	0.0009	0.0015
11	LOQ**	0.0027	0.0045

* Limit of Detection.
** Limit of Quantification.

concentration of Pb and Cd in varieties of onion (Table 2).

In Table 3 based on one-way ANOVA test between mean concentrations of Pb and Cd during the sampling seasons was not observed to differ significantly ($P > 0.05$).

According to one sample T-test it was found that the mean metal Pb is significantly different from the maximum limit measured with the national standard organization of Iran ($P < 0.05$) (Table 4).

The daily intake of Cd and Pb metals were assessed 0.043 and 0.096 mg $kg^{-1}day^{-1}$, respectively. The Provisional Tolerable Daily Intake (PTDI) for Pb and Cd metals are 0.00084 and 0.00009 mg kg^{-1} body weight respectively (ISIRI, 2010). Cd and Pb are important elements in consumers' potential risk of non-cancerous diseases; the non-cancer HI was calculated at 2.46×10^{-1}, which is lower than the base value (Table 5).

Evaluation of the hazard potential of cancer was evaluated in the range of 10^{-6}–10^{-4}.

Discussion

Contamination of agricultural products is important in point of view economic and hygienic and can play an essential role in the food security of humans. Therefore, it is imperative to have complete policy-making and comprehensive planning for quality food and the prevention of the prevalence of foodborne illness.

The WHO's recommended allowable concentration of Cd and Pb in plants are 100 and 300 μg kg^{-1} dry weight of the plant (Codex & Intergovernmental, 2001; Commission, 1995). Consistent with the present study, Nazemi et al. (2010) displayed that there is a major difference between the concentration of heavy metals in vegetables and the tolerable limit recommended by the standard (Nazemi, 2010).

The concentration of Cd in onion samples in Kurdistan and West Azerbaijan provinces was 2 and 5 times higher than the amount recommended by WHO/ FAO, respectively, and the amount of Pb in the samples of onion in Zanjan, Isfahan, Khuzestan, Tehran (Varamin), and Hormozgan province was less than the maximum permissible limit set by WHO/FAO. Mohajer et al. (2014) in Isfahan reported that the level of Pb in lettuce, cabbage, beet, and onion samples had 14, 8, 18, and 4 times higher than the tolerable range WHO-FAO, respectively. This pollution can be due to the municipal and industrial effluents in the area (Mohajer et al., 2014).

Evaluating the sensitivity of various kinds of onion to heavy metal intake from contaminated soil has been demonstrated that the content of Cr, Cd, and Pb in dry matter (DM) in onions exceeded the limit determined by the FAO (Bystricka et al., 2016). The concentrations of Pb and zinc in soil samples obtained from Mitrovica and Obiliqi areas were1953 – 2576–125 mg kg^{-1} and 138–179 mg kg^{-1}, respectively, their bioaccumulation rate was notably greater in onions compared to the control group (Gashi et al., 2020).

In the study of Abdollahi et al, the abundance of heavy metals except Cd is higher than the recommended level of WHO. The high level of metals in fields irrigated with effluent indicates bioaccumulation of metals in leaves (Abdullahi et al., 2009).

Amini et al. reported the mean amount of total Cd in the fields of Isfahan province as 1.79 mg kg^{-1}. They considered phosphorus fertilizers as the most important way of Cd entry to agricultural fields in the study area (Amini et al., 2005). The Hormozgan region has bioaccumulation of heavy metals particularly Cd, chromium, and Pb (Fakhri, 2015).

Table 2
Comparison between onion varieties with cadmium and lead content (μg kg^{-1}).

Heavy metals	Onion varieties	Mean ± S.D	F	P
Cd	Yellow variety	41.69 ± 35.74	0.499	0. 619
	Red variety	141.40 ± 193.97		
	White variety	102.02 ± 100.13		
Pb	Yellow variety	234.01 ± 202.21	0.080	0.923
	Red variety	204.63 ± 156.97		
	White variety	243.52 ± 174.50		

Table 3
Comparison between sampling season onion and concentration of the lead and cadmium (μg kg^{-1}).

Heavy metals	Seasons	Frequency	Mean ± S.D	P
Pb	Winter	15 (68.2%)	154.29 ± 163.68	0.401
	Autumn	7 (31.8%)	215.45 ± 135.14	
Cd	Winter	15 (68.2%)	44.39 ± 57.57	0.058
	Autumn	7 (31.8%)	148.76 ± 187.18	

Table 4
Comparison concentrations of heavy metals with maximum standard validity (μg kg^{-1}).

Heavy metals	Maximum allowable limit (ISIRI, 2010) μg kg^{-1}	t	P_{Value}	95% Confidence Interval of the Difference	
				Lower	Upper
Pb	100	2.236	0.036	5.16	142.34
Cd	50	1.068	0.298	−26.14	81.35

Table 5
Assessment of non-carcinogenic diseases and carcinogenic.

Heavy Metals	Concentration Index mg g^{-1}	daily valueg day^{-1}(ISIRI, 2010)	RfD (Li et al., 2013; USEPA, 2002; Yaradua et al., 2020)mg kg^{-1} day^{-1}	EDI mg $kg^{-1}day^{-1}$	HQ	Cancer Risk
Cd	0.0776	39	0.5	0.043	8.6×10^{-2}	
Pb	0.17375	39	0.6	0.096	1.6×10^{-1}	8.1×10^{-4}

Sharma et al. demonstrated that the average concentration of Cd in the studied vegetables was higher than the standard in India (1.5 mg/kg dry weight) (Sharma et al., 2008). The higher Cd level in their products compared to the same amount in this study can be attributed to the presence of Cd in the mentioned region's atmosphere and Cd absorption through atmospheric subsidence.

In the present study, no significant differences were observed between the means of heavy metals in different varieties (red, white, or local and yellow) of onions. In the study of Adil Ud Din the metal contents of Fe > Zn > Mn > Cu > Cr > Pb > Cd > Ni > Co were found in onions (local varieties) and the similar ones, respectively. The design of Zn > Fe > Cu > Mn > Pb > Ni > Cr > Cd was saw in onions (imported varieties). Cultivation systems, transportation, and vegetable markets play a vital role in increasing heavy metal pollutants (Din et al., 2013).

The hazard index for men and women in Isfahan was 2.6 and 2.9, respectively, which indicates the adverse effects of non-cancerous diseases, and the hazard of cancer in both groups of men and women was low (Salehipour Baversad et al., 2014). In the present study, the non-cancer risk for Pb and Cd is lower than the base value.

Unlike the present study the manganese, zinc, and iron concentration in onions grown in Katsina State except for Pb are commonly lesser than USEPA, WHO / FAO. Onion samples from Katsina State may help the cancer burden of society (Yaradua et al., 2020). Risk assessment Beijing residents of China through the consumption of vegetables showed among that heavy metals (Zn and As, Cr, Cu, Ni, Pb, Cd), arsenic had the highest portion of HI (Bo et al., 2009).

Conclusion

According to the results, although most of the onions sampled in different areas have two heavy metals, Pb, and Cd, more than the tolerable range recommended by the standard. However, consumers have no risk by estimating the amount of HQ in onion samples.

To better manage, prevent pollution, and also find the origin of elements, analyzing heavy metals content in the soil, water, and dust of these regions is recommended.

CRediT authorship contribution statement

Samira Shokri: Investigation, Writing – original draft, Writing – review & editing, Methodology. **Narges Abdoli:** Writing – original draft, Writing – review & editing. **Parisa Sadighara:** Writing – original draft, Writing – review & editing. **Amir Hossein Mahvi:** Writing – original draft, Writing – review & editing. **Ali Esrafili:** Writing – original draft, Writing – review & editing. **Mitra Gholami:** Writing – original draft, Writing – review & editing. **Behrooz Jannat:** Writing – original draft, Writing – review & editing, Supervision. **Mahmood Yousefi:** Investigation, Writing – original draft, Writing – review & editing, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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