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REVIEW ARTICLE

The mercury level in hair and breast milk of lactating mothers in Iran: a systematic review and meta-analysis

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Abstract
Exposure to mercury is one of the major global health concerns due to its stability, bioaccumulation and high toxicity. Therefore, the present study was conducted to assess the mean mercury level in hair and breast milk (BM) of Iranian lactating mothers (ILMs) through meta-analysis technique. We conducted a systematic literature search in online electronic databases included main domestic databases (SID, Magiran, Iran medex, Medlib and ISC) and international databases (Embase, Scopus and PubMed) for studies published between 2000 up 2018. Each process of research and evaluation of articles based on inclusion and exclusion criteria is done by two researchers, individually. From10 studies entered to meta-analysis process including 556 ILM, the mean hair mercury level (HML) and mean milk mercury level (MML) was estimated to be 0.15 μg/g (95 CI: 0.11–0.19, I2: 47.6%, P: 0.028) and 0.51 μg/l (95 CI: 0.28–0.74, I2: 1.9%, P: 0.421), respectively. In this meta-analysis, the mean HML and mean MML were estimated to be lower than the standard of World Health Organization (WHO). Although the mean mercury level in hair and BM of ILMs was lower than the WHO standard, but due to toxicity and serious concern of health, management and Periodic monitor are recommended in different cities of the country for evaluate the mercury levels in hair and BM of ILMs and to estimate the infant's exposure.

Keywords Mercury · Hair · Breast milk · Mothers, Iran

Abbreviations

WHO	World Health Organization
MML	milk mercury level
HML	hair mercury level
SD	standard deviation
HBM	human Breast Milk
BM	Breast Milk
ILMs	Iranian lactating mothers

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Introduction

Metals are abundant in everywhere on Earth's crust, but exposure to some metal pollutants such as arsenic, Lead (Pb), mercury (Hg) and cadmium (Cd) are dangerous and carcinogenic to humans even at very low concentrations [1]. Among the harmful metals to humans, mercury is the as most toxic element known after arsenic and lead, that situated in third rank of pollutants with highest priority by the National Priorities List of the Agency for Toxic Substances and Disease Registry (ATSDR) [2].

Mercury is one of the heavy metals found in water, soil and air that widely enter the environment from through natural and anthropogenic sources [3, 4]. Natural releases of mercury into environment enter through natural sources including the weathering of Hg-containing rocks, geothermal activities, and volcanicity, while the most releases are associated to anthropogenic activities [5, 6].

Also, mercury releases from main sources of anthropogenic is included of the mining, smelting, and production of iron and non-ferrous metals, combustion of coal and other fossil fuels, large-scale gold production, mine production of mercury, cement production, oil refining, contaminated sites, waste of result from consumer products (landfill (mostly) and waste incineration), chlor-alkali industry, Cremation (dental amalgam) and etc. [3, 7].

The other potential sources for human exposure to mercury, is including thermometers, sphygmomanometer, barometers, incandescent lights and batteries and various commercial products including skin creams, germicidal soaps, various medications, teething powders, analgesics, vaccinations and thimerosal (preservative in vaccines) [8].

In recent years, mercury pollution and dangers of it has become a global concern which this topic has led to various conventions such as minamata convention to manage it, the treaty which dedicated purely to mercury. In accordance with article 19 of the Minamata convention, which its main aim is protect the environment and human health, demands from member countries of convention to endeavor and assess the effects of mercury and its compounds on damageable populations such as infants, children, pregnant and lactating women [9].

Mercury is one of the most dangerous environmental pollutants due to environmental sustainability and bioaccumulation in the food chain. Their three main forms are include of elemental mercury (Hg^0), inorganic mercury (Hg^{+2}) and organic mercury (MeHg) [10]. All forms of mercury are extremely toxic and harmful to human health. Humans through food, water, air and occupational exposure may be exposed to mercury.

Mercury is the only metal that is liquid in its elemental form. In this state, metal easily evaporates at room temperature and inhalation causes toxicity in humans. The elemental form of mercury is soluble in lipid and readily enters the bloodstream through the alveolus after inhalation, which in this position, the results to bioaccumulation of mercury in the renal cortex, liver, and especially the brain [11].

Inorganic mercury (mercurous and mercuric state) is absorbed by the digestive system and in mercuric salts is more soluble and toxic than elemental form [12]. the main source of exposure whith inorganic mercury is a dental amalgam [13].

The forms of organic mercury include methyl mercury and ethyl mercury. The most dangerous mercury form of organic is dimethyl mercury which is highly toxic. The most usual form of organic mercury is methyl mercury, which is often transformed by microorganisms to other more toxic forms such as methyl mercury in the water, soil and body tissue of creatures [14, 15]. Consuming food such as fish (or other seafoods) and vaccines containing thimerosal are the most important sources of human exposure whith organic mercury, which about 95% of it is absorbed in the digestive system [16–18].

The toxic effects of mercury for humans are related to many factors like the chemical form, dose and exposure rate (quantity, frequency, and duration) [11, 19].

As mercury is potentially toxic, depending on its form, the effects of exposure to mercury and its compounds from natural and anthropogenic sources on humans it can cause irreversible damage to the systems of Neurological (Alzheimer, Erethism, Dementia, Parkinson, Schizophrenia) [20–25], Renal [26–28], respiratory [29–31], immunological [11, 32], Genetic and epigenetic Outcomes [33, 34], Cardiovascular (Arrhythmi, Cardiomyopathy, Irregular pulse, Chest pains) [35–38], and Reproductive Outcomes (Birth defects, Impotency, Impair fertility) [39–41].

Exposures with mercury can be estimated by measuring pollutant levels in various body tissues (such as hair, milk, blood, urine, or nails). Measuring mercury levels in these tissues can be well indicators for different types of mercury exposures [10].

Exposure of women to toxical metals such as mercury during the Pregnancy and Breastfeeding time, even at very low doses, can have effects on fetal and infant growth [42]. During pregnancy, mercury easily crosses the placenta, concentrates in the fetus, and ultimately crosses the fetal blood–brain barrier and it causes brain damage to the developing fetus [43].

It can also be transmitted after birth in the Breastfeeding time to the mammary glands of the Iranian lactating mothers (ILMs) [44].

human breast milk (HBM) of as the best source of nutrition for infants, depending on the mother's exposure, may contain harmful contaminants such as mercury, so, the exposure to mercury can be injurious effects on infants [45–47]. Once mercury enters the hair, it will no longer returns to the bloodstream and shows a relatively direct relationship with blood mercury levels, so, hair is a good index for evaluating the accumulation of mercury in the body and estimate long- term exposure [48].

In order to perform a risk assessment, exposure results were compared with guidelines of World Health Organization (WHO) [10, 49, 50].

So, the investigation and measurement of this pollutant in hair and Breast Milk (BM) of ILMs is very important to improve the health of mothers and infants.

Various studies have examined the amount of mercury in the hair and milk of ILMs [51, 52]. But, findings are inconsistent in this regard. Specifically, the results of this study can be used to control global mercury pollution to evaluate the effectiveness of the Minamata Convention.

Therefore, the present study was conducted to assess the mean mercury level in hair and BM of ILMs through a systematic review and meta-analysis technique.

Materials and methods

Search strategy

We conducted a systematic search in online electronic databases included main local databases (SID, Magiran, Iran medex, Medlib and ISC) and international databases (Embase, Scopus and PubMed) for studies published (between 1 January 2000 up 31 December 2018) using the following key terms: “heavy metals”, “mercury”, “human milk”, “breast milk”, “Hair”, “mothers” and “Iran” to select related studies. For online electronic databases of national, an equivalent of Persian keywords was used.

Study criteria

Inclusion criteria

The inclusion criteria for studies entered in the meta-analysis process were as follows: 1) the studies of published to Persian and English languages; 2) studies conducted inside Iran; 3) samples containing the mean mercury concentration in hair and BM of ILMs and 4) article of published from 1 January 2000 up 31 December 2018.

Exclusion criteria

The Exclusion criteria were as follows: 1) Articles written in a language other than Persian or English; 2) studies conducted outside Iran; 3) samples containing of non- ILMs or pregnant women; 4) samples containing of mean concentration the other heavy metals (Except of mercury) in hair and BM of ILMs; 5) Studies that did not report mean and standard deviation; and 6) articles that unavailability of information. Also articles that did not have a cross-sectional design or conducted on animals were excluded.

Selecting studies

We reviewed the results of all the studies, and excluded some articles after reviewing based on the titles and abstracts. Two reviewers independently carried out the literature search and evaluation of the searched articles based on the inclusion and exclusion criteria. The search strategy and review processes in present study are in accordance with guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [53]. In the present study, articles qualified for further analyses were collected with initial screening of identified titles or abstracts. Eligible studies were screened against predefined inclusion and exclusion criteria. Then, full text of studies was reviewed to determine of these two referees independently. After accurate review of studies, differences were resolved with consensus or if needed by a third reviewer.

The details and flow diagram of literature review process is given in Fig. 1.

Data extraction and selection

The extracted data were as follows: name of first author, publication year, study place (province and city), sample size, study design, mean of mercury concentration level with standard deviation (SD), analytical technique and age range.

Quality assessment and risk of Bias

The quality of all studies were assessed by Modified Newcastle-Ottawa Scale for cross sectional studies [54]. A score of >7 on the NOS scale for each study, was considered to have a low risk of bias and an excellent methodological domain. Finally, the articles were categorized as low, moderate and high.

Meta-analysis

After data extraction, STATA version 15.0 (Stata Corporation, College Station, TX, USA) was used for meta-analysis. Mean and SD were reported for eligible papers. A Cochran Q test was conducted to assess heterogeneity and an I^2 statistic was calculated to estimate the percentage of total variation resulting from between-study variation [55]. Low, moderate or high degrees of heterogeneity were approximated by I^2 values of 25%, 50% and 75%, respectively. Heterogeneity was assessed by subgrouping the time of measures, and study population. Publication bias was assessed by Egger and Begg’s test with a significance level of 0.10. In addition, we planned to plot funnel plots if we encountered more than 10 studies for each forest plot; however, the number of studies was not found to be adequate for such plotting.

Results

Search results and studies description

The primary literature searches showed 619 articles, which in databases of Embase, Scopus, PubMed and other databases identified 320, 48, 221 and 31 articles, respectively. After removing duplicates, a total of 605 articles were residual for review. Then, 605 articles were excluded after identification based on titles, abstracts and full-text. Totally, 11 main studies were eligibility for inclusion and exclusion criteria (5 studies dealt with the mercury level in hair of ILMs and six studies dealt with mercury level in BM of mothers). Finally, 10 eligible studies (Hair: Five study, Milk: Five study/ conducted from 2000 to 2018 in 15 of Iran cities) entered the meta-analysis process. The sample size for studies on hair and milk, were 279 and 277, respectively.

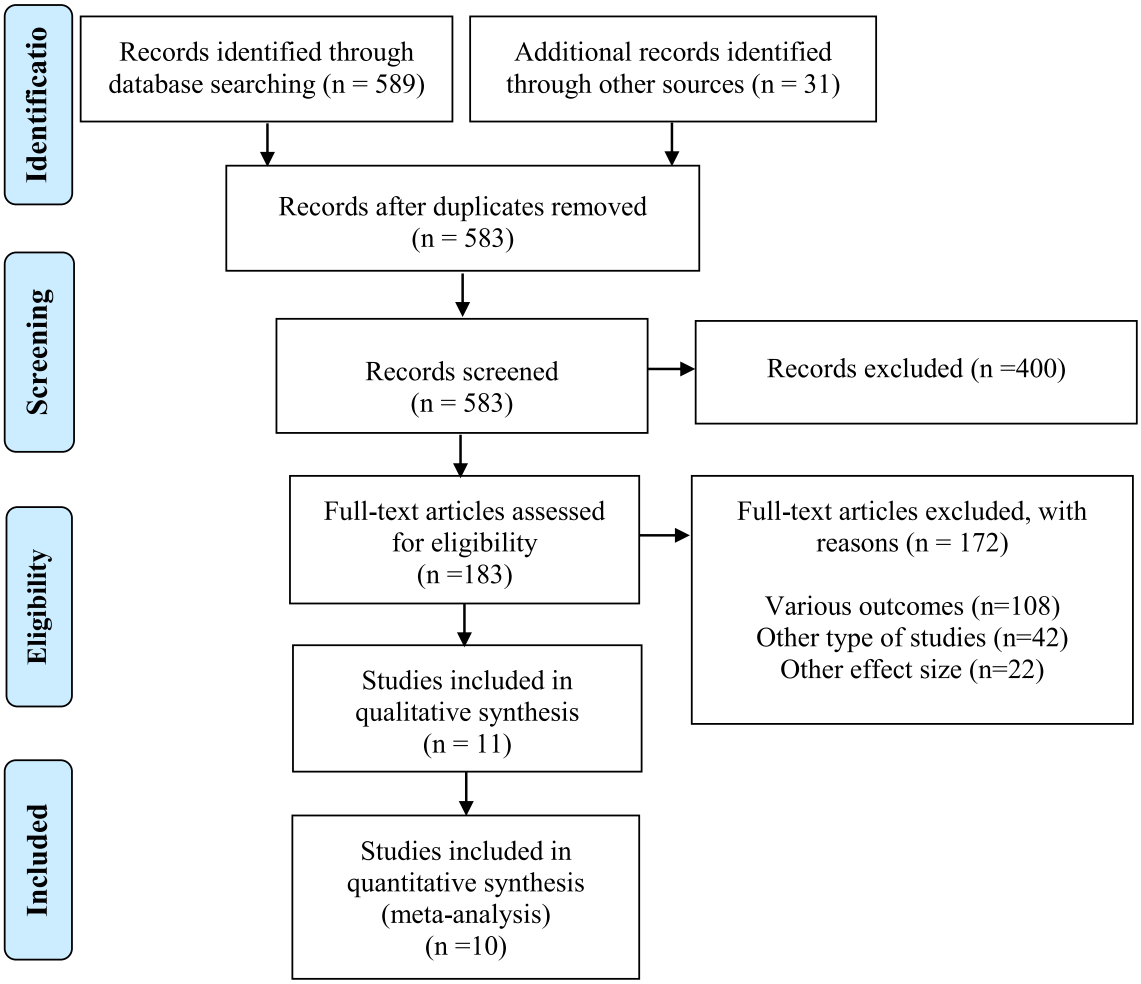

Fig. 1 PRISMA flow diagram for selecting studies of systematic review

One study [56] reported mean mercury level (3.48 μg/L) in BM of ILMs, but do not entered the meta-analysis process due to the lack report of SD (Fig. 1).

The detail data collected from the final included studies and samples specifications are shown in Table 1.

Generally, from 10 studies entered to meta-analysis process, mothers age range in done studies on hair and BM of ILMs were 17 to 36 years and 16 to 38 years, respectively.

The lowest and highest number of hair and HBM samples in meta-analysis process, varied from 6 to 93 samples and 37 to 82 samples, respectively. Overall, the risk of bias in primary studies was low (Table 1).

Mean mercury level in hair and BM of ILMs

The mean of mercury was obtained to be 0.15 μg/g (95 CI: 0.11–0.19, I^2: 47.6%, P: 0.028) and 0.51 μg/l (95 CI: 0.28–0.74, I^2: 1.9%, P: 0.421) in hair and BM of ILMs, respectively (Fig. 2).

Since the confidence interval (CI) of the test not includes zero (Egger's Test: t = 1.24, $p = 0.0001$, CI 95% = 0.73 to 1.75), significant bias occurred in the publication of the results (Fig. 3).

According to guideline of WHO, for hair and BM of ILMs, four and five studies had lover mercury levels than the limit declared by WHO, respectively.

Based on Table 1, the lowest and highest the mean of mercury level in hair related 0.11 μg/g and 4.2 μg/g, respectively. Also, the lowest and highest mean of mercury in HBM reported 0.12 μg/l 7.57 μg/l, respectively.

Also, to better highlight of mercury levels in hair and BM of ILMs according to WHO standard, the map of spatial distribution of mean mercury concentrations was generated by using a Geographic Information System (Fig. 4).

Analytical methods and results reporting

Generally, milk samples of ILMs were collected manually (one study with pump) and then stored in polyethylene (4 study) and polypropylene (one study) containers. Also, the retention temperature of the samples was in range -18 °C to 20 °C.

Table 1 The detail of literature studies in hair and BM of lactating mothers (2000–2018)

Study/ Year	Place (Province)	Place (City)	Sample Size	Study Type	Mean of Mercury Level (Mean ± SD/ Rang)	Analytical Technique	NOS Score
Hair (μg/g)							
Khammar et al. [57], 2017	Sistan and Baluchestan	Zahedan	40	Cross-sectional	1.81 ± 0.54 (0.67–3)	HR-CS-AAS	7
Okati et al. [58], 2012	Mazandaran	Nowshahr, Nur and Sari	93	Cross-sectional	3.55 ± 2.52 (0.08–8.97)	AMA-S-PAAS	8
Okati et al. [58], 2012	Mazandaran	Nowshahr	27	Cross-sectional	4.2 ± 2.77 (0.13–8.97)	AMA-S-PAAS	8
Okati et al. [58], 2012	Mazandaran	Nur	39	Cross-sectional	3.3 ± 2.53 (0.08–8.45)	AMA-S-PAAS	8
Okati et al. [58], 2012	Mazandaran	Sari	27	Cross-sectional	3.27 ± 2.19 (0.11–7.42)	AMA-S-PAAS	8
Savabieasfahani et al. [59], 2012	Tehran	Tehran	6	Cross-sectional	0.19 ± 0.12	ICP-MS	6
Ghasempouri et al. [60], 2012	Mazandaran	5 Regions	70	Cross-sectional	0.19 ± 0.09 (0.06–0.43)	AMA-S-PAAS	8
Ghasempouri et al. [60], 2012	Mazandaran	Nowshahr	10	Cross-sectional	0.29 ± 0.08 (0.18–0.40)	AMA-S-PAAS	8
Ghasempouri et al. [60], 2012	Mazandaran	Nur	8	Cross-sectional	0.24 ± 0.12 (0.12–0.43)	AMA-S-PAAS	8
Ghasempouri et al. [60], 2012	Mazandaran	Chamestan	17	Cross-sectional	0.14 ± 0.09 (0.08–0.42)	AMA-S-PAAS	8
Ghasempouri et al. [60], 2012	Mazandaran	Village of Nur	13	Cross-sectional	0.16 ± 0.04 (0.08–0.24)	AMA-S-PAAS	8
Ghasempouri et al. [60], 2012	Mazandaran	Village of Nowshahr	22	Cross-sectional	0.11 ± 0.03 (0.06–0.38)	AMA-S-PAAS	8
Okati et al. [61], 2010	Mazandaran	Mazandaran	70	Cross-sectional	0.19 ± 0.09 (0.06–0.43)	AMA-S-PAAS	7
Milk (μg/L)							
Bahmani and Maleki [56], 2018	Kurdistan	Sanandaj	100	Cross-sectional	3.48 (0.9–3.56)	ICP-MS	7
Khammar et al. [57], 2017	Sistan and Baluchestan	Zahedan	40	Cross-sectional	1.23 ± 0.306 (0.21–1.7)	HR-CS-AAS	7
Okati et al. [62], 2013	Mazandaran	Amol and Sari	82	Cross-sectional	0.43 ± 0.55 (0–2.45)	AMA-S-PAAS	8
Okati et al. [62], 2013	Mazandaran	Amol	38	Cross-sectional	0.37 ± 0.15	AMA-S-PAAS	8
Okati et al. [62], 2013	Mazandaran	Sari	44	Cross-sectional	0.50 ± 0.71	AMA-S-PAAS	8
Goudarzi et al. [63], 2013	Isfahan	Isfahan	37	Cross-sectional	0.92 ± 0.54 (0–2.07)	CV-AAS	6
Norouzi et al. [64], 2012	Isfahan	Lenjan	38	Cross-sectional	7.57 ± 1.08	AMA-S-PAAS	8
Dahmardeh Behrooz et al. [65], 2012	Tehran, Mazandaran and East Azerbaijan	Tehran, Noushahr and Tabriz	80	Cross-sectional	0.39 ± 0.1 (ND* - 5.86)	AMA-S-PAAS	7
Dahmardeh Behrooz et al. [65], 2012	Tehran	Tehran	34	Cross-sectional	0.12 ± 0.06 (ND* - 1.73)	AMA-S-PAAS	7
Dahmardeh Behrooz et al. [65], 2012	Mazandaran	Noushahr	18	Cross-sectional	0.15 ± 0.06 (ND* - 1.21)	AMA-S-PAAS	7
Dahmardeh Behrooz et al. [65], 2012	East Azerbaijan	Tabriz	28	Cross-sectional	0.86 ± 0.26 (0.02–5.86)	AMA-S-PAAS	7

ND*: Not detectable

Also, hair samples in all studies were collected from scalp area of ILMs. The amount of hair needed was for mercury analysis in four study 1 g and in one study about 2–5 g. In all studies, hair samples were cut with stainless steel scissors and then stored in labeled plastic bags.

In the selected studies, mean mercury levels in hair and BM of ILMs were reported in two types of units, μg/L and μg/g, respectively.

The BM mercury content of ILMs was obtained in three studies by Advanced Mercury Analyzer- Single-

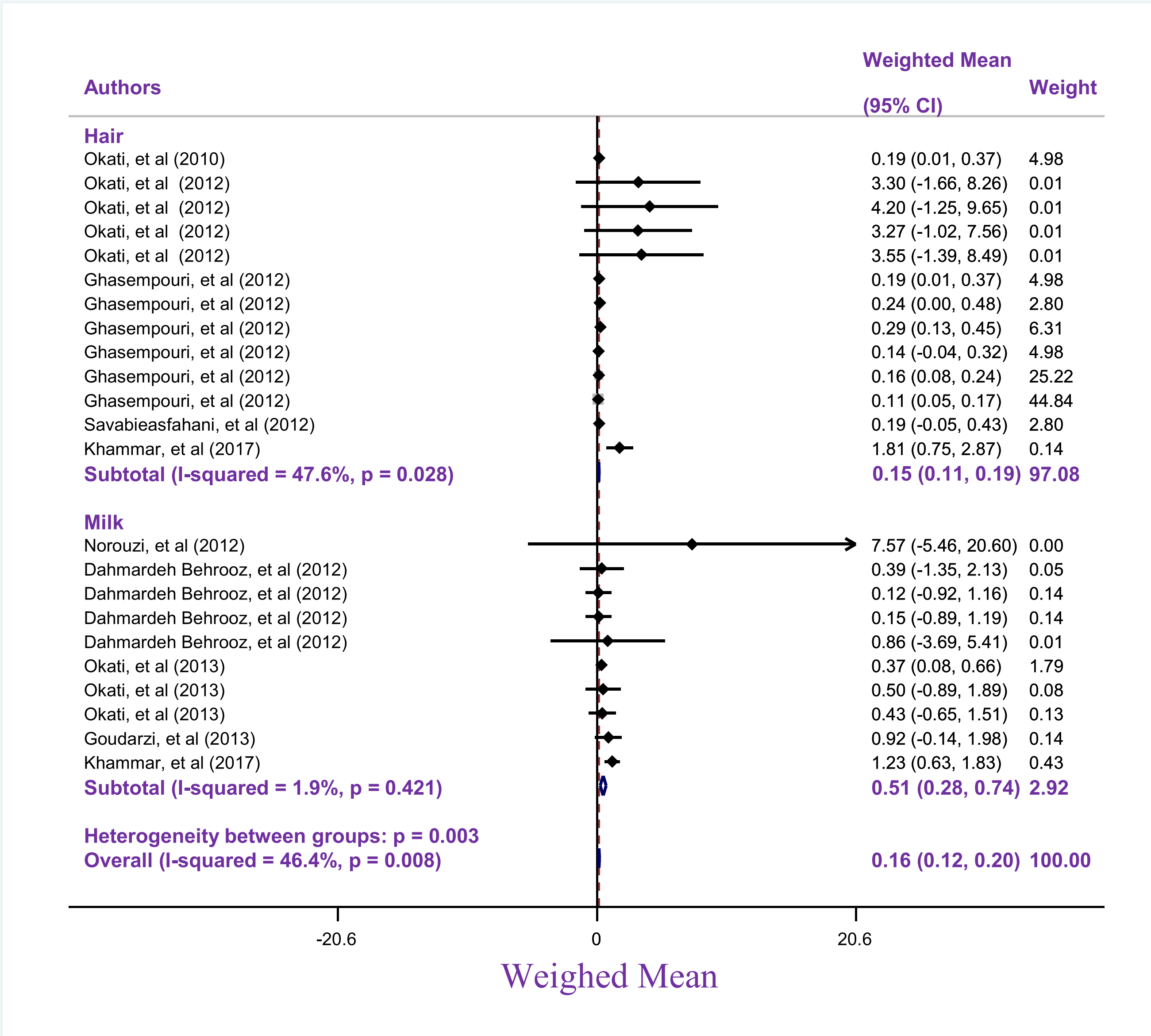

Fig. 2 Subgroup analysis Weighed mean of Mercury in Mother based on sample environment (Heir and Milk) in Iran

Purpose Atomic Absorption Spectrometer (AMA-S-PAAS); however, the one study used the Cold Vapor Atomic Absorption Spectroscopy (CV-AAS). Also, two other studies used the mass spectrometry Inductive Coupled Plasma (ICP-MS) and High-Resolution-Continuum Source Atomic Absorption Spectroscopy (HR-CS-AAS).

The hair mercury content of ILMs was obtained in three studies by Advanced Mercury Analyzer- Single-Purpose Atomic Absorption Spectrometer (AMA-S-PAAS). Also, two other studies used the mass spectrometry Inductive Coupled Plasma (ICP-MS) and High-Resolution-Continuum Source Atomic Absorption Spectroscopy (HR-CS-AAS), respectively.

Meta-regression

The Meta regression was used to detect association between independent variables (age and years of publication) and dependent variable (mean of mercury in hair and BM). Results of Meta regression show that the mean of mercy in BM of ILMs did not have association with age (coefficient: 0.035, P: 0.980, 95% CI: −10.61, 10.68) and years of publication (coefficient: -0.025, P: 0.921, 95% CI: −58.73, 58.75). Also results of Meta regression show that the mean of mercury in hair did not have association with age (coefficient: 0.316, P: 0.672, 95% CI: −17.41, 18.04) and years of publication (coefficient: -0.268, P: 0.880, 95% CI: −83.67, 83.00).

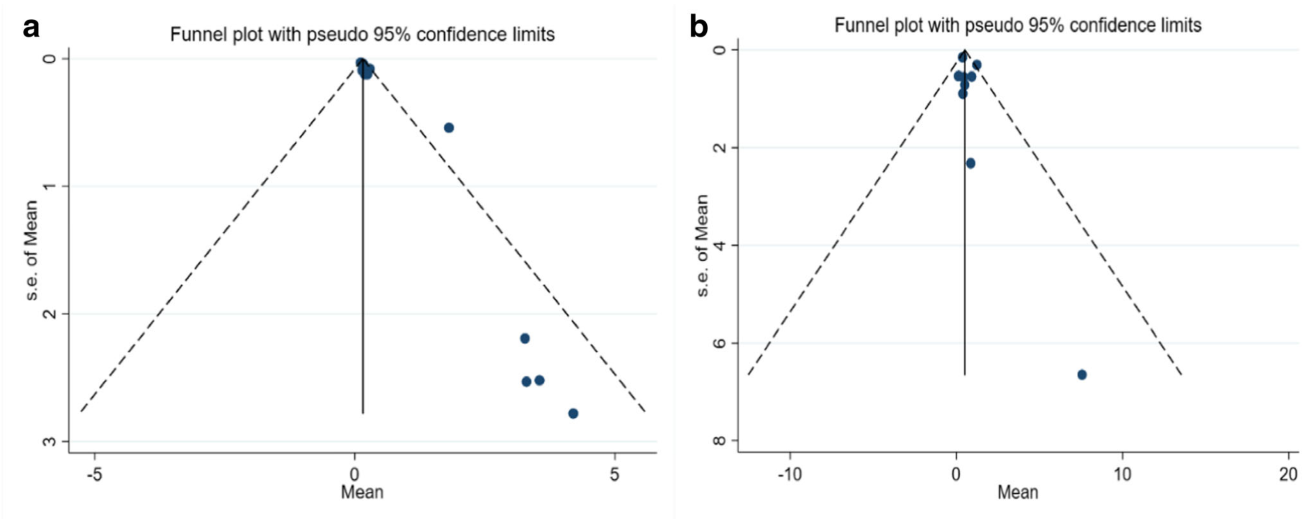

Fig. 3 Publication bias of weighted Mean of Mercury in mother in Iran (A: Milk, B: Hair)

Discussion

Successful management and implementation of the Minamata Convention for protect human health and the environment depends on the support of appropriate scientific research and data.

Therefore, to enhance public health research, promote health, population benefit and protection against mercury

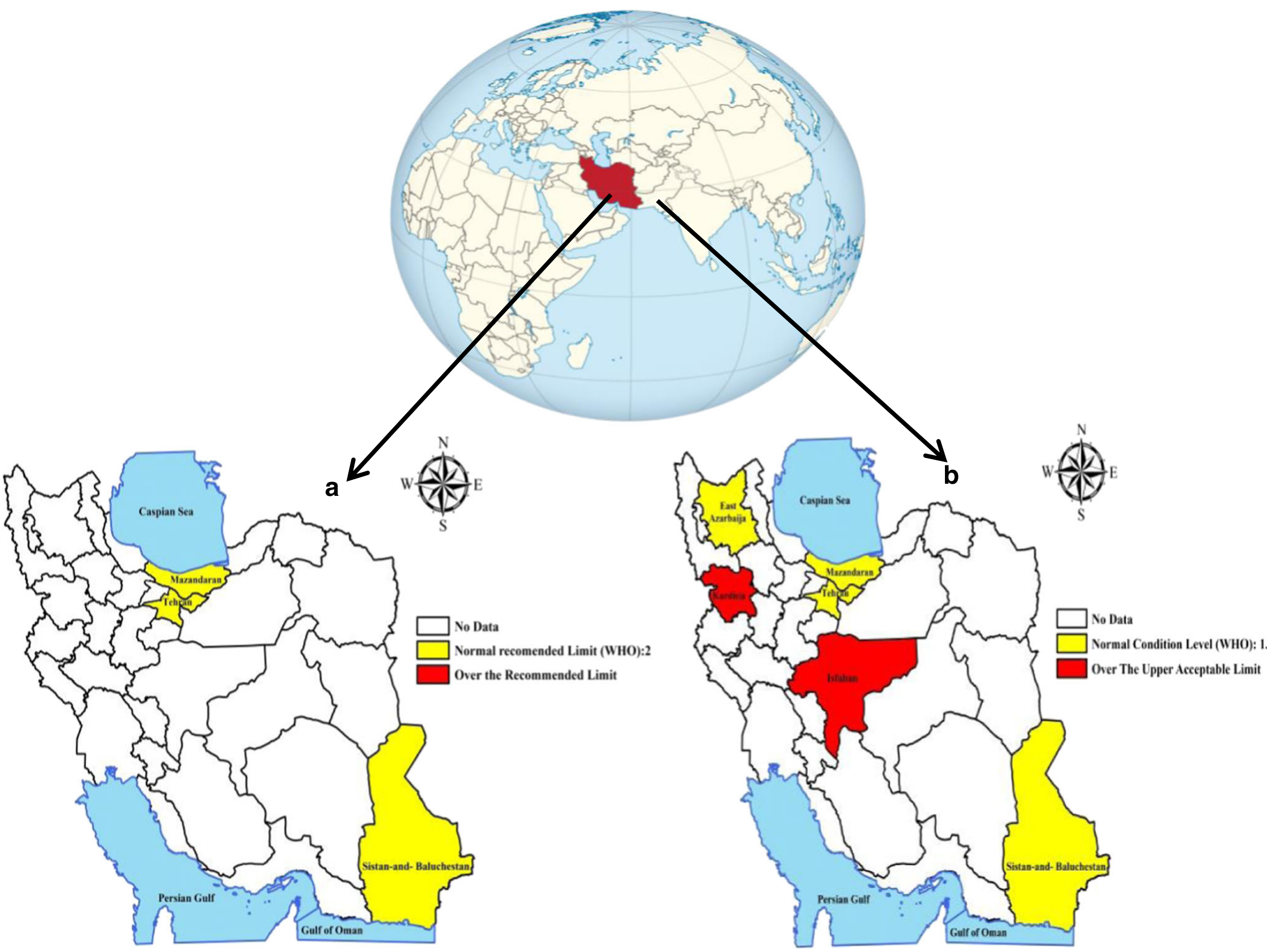

Fig. 4 The geographical distribution of mercury levels in hair (**a**) and BM (**b**) of ILMs accord ing to WHO standard

exposure, we need to have a general understanding of the current situation for planning and formulating appropriate policies in the future.

In the current review study, to the best of our knowledge, for the first time, we determined the mean mercury level in hair and BM among ILMs population.

Hair and HBM are considered as two suitable bio-indicator of mercury contamination for determination of human risk factors in study of toxic metals.

According to Guideline of WHO, the mercury level of 1.4–1.7 μg/l and 2 μg/g were considered as "normal condition levels" in BM of human [49, 50] and "Normal Recommended Limit" in mother's hair, respectively [10].

Mean of mercury level in milk was estimated to be 0.51 μg/l (95 CI: 0.28–0.74, I^2: 1.9%, P: 0.421) for ILMs.

The results of present research indicated a low rate of mean milk mercury level (MML) in ILMs compared with the WHO standard. This is probably due to their low fish consumption and their relatively low mercury levels.

In this meta-analysis, about 37% of the total samples size, the mercury level in milk was reported to be higher than the allowable limit of WHO [56, 64].

The most important risk factor for increasing mercury concentrations in BM is the consumption of mercury-contaminated foods such as fish [10].

In the Bahmani and Maleki study [56] in Kurdistan, since the use of dental amalgam by ILMs was negligible and there was a significant correlation between the MML and fish consumption, so the high MML may be due to high fish consumption.

This is consistent with the results of other studies [48, 62, 66–68]. But in other studies there was no significant relationship found between fish consumption and mercury concentration in BM [69–76].

Also, another risk factor for increasing mercury concentrations in BM is exposure to mercury vapor via amalgam-filled teeth during pregnancy and lactation.

Accordingly, in the study of Norouz et al. [64] in Esfahan, The fish consumption was very low among mothers and there was a significant positive correlation between MML and dental amalgam, which probably the high MML may be due to it. So that the mean milk mercury level in mothers with one to three amalgam-filled teeth and mothers with four to eight amalgam-filled teeth increased from 5.47 μg to 13.33 μg.

Other studies have reported levels above the WHO standard. This rate varies In different countries of the world: Italy (2.6 μg/l) [75], Turkey (3.42 μg/l) [73], Turkey (25.8 μg/l) [72], Brazil (5.7 μg/l) [77], Brazil (5.73 μg/l) [78], Brazil (6.7 μg/l) [71], Brazil (59.41 μg/l) [79], Indonesia, Tanzania and Zimbabwe (1.87 μg/l) [74], and Mexico (2.52 μg/l) [80].

The mean MML in ILMs varies in worldwide, which are within the range of 0.008–59.41 μg/l [79, 81], which in present study was within the range of 0.12–7.57 μg/l.

Various studies have considered different factors to be effective on mercury concentration. These factors include: sampling location, sampling time, sampling method, lactation period, fat content of milk, nutritional status and maternal exposure level [10]. However, factors such as the method of analysis of samples and contaminated samples may also influence the final results.

Although MML are not the same in different countries, but the results of this study are consistent with results from other studies: Saudi Arabia (1.191 μg/l) [45], Korea (0.94 μg/l) [82], Cyprus(0 ± 0.20 μg/l) [83], Saudi Arabia (0.970 μg/l) [84], United Arab Emirates (0.008 μg/l) [81], Slovakia (0.94 μg/l) [85], Austria (1.59 μg/l) [86], Japan (0.81 μg/l) [87], Spain (0.53 μg/l) [68], Brazil (0.36 μg/l) [70], and United Arab Emirates(0.115 μg/l) [88].

Chien et al. [89] In a study estimated that over 99% of mercury exposure in infants was caused by BM. Therefore, BM is a major source of mercury exposure for infants and its consumption can cause serious harm to infants, including nerve damage, immune problems, mental retardation, cerebral palsy, motor disorders, visual impairment, speech and hearing impairment [58, 89, 90].

The results showed that the mean hair mercury level (HML) was estimated to be 0.15 μg/g (95 CI: 0.11–0.19, I2: 47.6%, P: 0.028) for ILMs.

Overall, the mean HML in ILMs was within the range of 0.11–4.2 μg/g. The results of this study showed that the mean HML in ILMs compared with the allowable limit of WHO is lower, which is probably due to their low fish consumption و their relatively low mercury levels and low amalgams consumption.

In accordance with guideline of WHO, in our study the HML was higher than allowable limit [58].

In this study, there was a significant positive correlation between HMLs and fish consumption as well as amalgam use by ILMs. However, as the concentration of mercury in the mothers without amalgam was also high in this study, this was probably due to the high levels of mercury in the hair and the main exposure of mothers to high fish consumption.

Although fish consumption is an effective factor in increasing the mercury concentration in ILMs, the use of other sources such as cosmetics or chemical shampoos can potentially affect the amount of mercury in hair [91, 92].

Today, mercury-containing cosmetics such as bleach, skin-lightening creams and other beauty products are widely used by women worldwide. Therefore, it is important to provide information on the dangers of this subject, especially for pregnant and ILMs about the care and non-use of these substances [93].

On the other hand, there was no significant relationship between the date of publication and the age of mothers with the mean mercury level in this study, which suggests that there may be other variables that have significant effect on mercury levels in BM and hair.

Thus, although the mean HML of ILMs is not the same in different countries, but the results of this study are consistent with studies in other countries, such as: Spain (1.22 μg/g) [13], Slovakia (0.13 μg/g) [94], Germany (0.109 μg/g) [95], 17 European countries (0.1–1.486 μg/g) [96], and Slovenia (0.377 μg/g) [97].

Limitation:

We observed the heterogeneity of mercury measurement units between different studies in hair and BM of ILMs. Therefore, their analysis was performed separately.

Also, another limitation of the study presented here is that data are not totally representative of a country population.

In addition, exposure with mercury in other studies reporting using biometrics such as blood, urine, nails were not contained in our analysis because of the lack of study in this field.

Therefore, the results of the present study are an overview of the information on mean mercury levels in hair and BM of ILMs, and it doesn't necessarily show the level of mercury exposure in our country.

Conclusion

Mercury is one of the most dangerous environmental pollutants due to environmental sustainability and bioaccumulation in the food chain.Pregnant and ILMs exposure to mercury and subsequent infant exposure to BM is one of the most important health concerns in the world due to its high toxicity. Exposure to this substance by mothers and infants can cause serious harm to them. In this study, studies conducted on mercury concentrations in hair and BM of ILMs were reviewed. The concentration values of these substances were also compared with WHO standards. While the mean total mercury level in hair and BM of ILMs was lower than the WHO standard, but due to the toxicity and dangers of mercury exposure, management and periodic monitoring of mercury levels in ILMs and newborns in different cities in the country are essential. It is also important to identify all potential risk factors for mercury exposure.

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Compliance with ethical standard

Conflict of interest The authors of this article declare that they have no conflict of interests.

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