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Health risk assessment of heavy metals in Malay herbal medicine (MHM) consumed by pregnant and postpartum mothers

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Abstract

Background Malay herbal medicine (MHM) is a popular medication and supplementation among Malaysian mothers during pregnancy and postpartum. It is expected to improve the baby's health, increase breastmilk production, promote slimming and uterine involution, and improve the mother's general health. Recent increases in reports of heavy metal contamination have raised safety concerns.

Objective This pilot exploratory study employed a comparative cross-sectional design to investigate the types of MHM ingested during pregnancy and postpartum, their possible heavy metal contamination and associated health risks.

Method This study involved 167 healthy postpartum Malay women.

Findings MHM consumption was significantly associated with the mother's number of pregnancies and children ($p < 0.05$) as well as her pre-pregnancy weight ($p < 0.05$). Mothers who consume MHM were twice as likely (95% CI 1.077–3.963) to experience threatened abortion. Heavy metals were detected in the three most widely consumed MHM samples. The mean concentration of heavy metals in these samples were 47.44 ± 67.74 μg/kg for As, 25.34 ± 2.48 μg/kg for Cd, 3685.87 ± 5683.36 μg/kg for Cr and 194.33 ± 195.19 μg/kg for Pb. The calculated non-carcinogenic hazard health risks (HQ) and health index (HI) were less than one, suggesting no adverse health impacts under the exposure conditions studied.

Conclusion While the HQ and HI values indicate no immediate health risks, the potential transfer from mother to foetus during pregnancy and from mother to infant during breastfeeding warrants further investigation. Additional studies are essential to confirm our findings and monitor the health of mothers and infants.

Keywords Heavy metals · Malay herbal medicine · Pregnancy · Postpartum · Non-carcinogenic health risk

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1 Introduction

The role of medicinal plants in cosmetics, food supplements and pharmaceuticals has increased in recent decades due to the renewed interest in traditional and natural health remedies [1–3]. The World Health Organization (WHO) estimated Malaysia's traditional complementary and alternative medicine industry to be worth more than USD 250 million annually [4]. A previous report showed Malaysia has a high prevalence of herbal usage of up to 70% [5], with Malay women having more tendency for consumption than other ethnic groups [6, 7]. Traditional Malay herbal medicine (MHM) in Malaysia is rooted in Arabic Unani medicine and Galenic philosophy, and is influenced by Indonesian, Chinese, Indian, and indigenous traditional medicine [8]. Malaysian mothers use herbal medicine throughout their pregnancy and postpartum to improve the health of their babies, increase breastmilk production, promote slimming and uterine involution, and boost mothers' general health [9–13]. Herbal treatments are often favoured over conventional medicine, perceived as crucial for promoting health and well-being, especially during pregnancy. Malay women commonly use raw herbs and herbal products, relying on specific theories, cultural beliefs, and societal experiences for medicinal purposes. Most ethnic groups in Malaysia believe that herbal products are safer and have fewer side effects compared to pharmaceutical drugs. However, the increasing use of these products without considering their potential health risks poses dangers to both mothers and their children [14].

Concerns over the use of herbal treatments at home grew after global reports showed high levels of heavy metal contaminations. Heavy metal poisoning is a significant environmental hazard, especially during pregnancy and early development, a risk that is often overlooked [15]. Heavy metals are metals and metalloids with atomic numbers greater than 20. Heavy metals such as cadmium (Cd), arsenic (As), chromium (Cr), and lead (Pb) are naturally found in the earth. Nonetheless, they are ubiquitous in the environment due to anthropogenic activities such as agriculture, mining, and industry. These toxic heavy metals pollute the environment, get absorbed into the soil and accumulate in plants, including those used for medicinal purposes [16]. Several studies found heavy metal contaminations in medicinal plants from Brazil, China, Egypt, Ghana, Mali, Nigeria, and South Africa, highlighting serious safety concerns regarding herbal medicines [15, 17–22]. The accumulation of heavy metals in these plants not only compromises the quality of the material but may also diminish their therapeutic properties [19, 23, 24].

Heavy metals present in contaminated medicinal plants can cross the placenta and enter breast milk, posing serious risks to fetal and infant development. These metals induce oxidative stress by generating reactive oxygen species (ROS), which can lead to lipid peroxidation, DNA damage, and enzymatic dysfunction [25–28]. Specifically, lead exposure during pregnancy can cause congenital heart disease [29, 30]. Prenatal heavy metal exposure has been associated with several health problems in later life, including intellectual deficits [31], diabetes [32, 33], attention deficit hyperactivity disorder [34, 35] and immune dysregulation [36]. Moreover, prenatal heavy metal exposure can adversely affect maternal health. For instance, arsenic found in maternal urine has been associated with fever, nausea, and diarrhoea during pregnancy, which can compromise fetal development due to poor nutritional status [37]. Additionally, exposure to extremely low cadmium concentrations can stimulate uterine contractility, resulting in preterm birth [38].

Previous research reported health risks associated with the consumption of traditional herbal medicine during pregnancy and postpartum [9, 10, 39, 40], but these studies did not specifically address the MHM. Current scientific evidence of heavy metal contamination in MHM consumed by Malaysian pregnant and postpartum mothers remains sparse. As such, this pilot exploratory study aimed to investigate the types of MHM consumed during pregnancy and postpartum, its possible contamination by toxic heavy metals, and evaluate the associated health risks.

2 Materials and Methods

2.1 Study Design and Questionnaire

This pilot exploratory study utilized a comparative cross-sectional design to assess the use of MHM among pregnant and postpartum mothers. A total of 167 healthy Malay women were enrolled, consisting of 84 MHM consumers and 83 non-consumers residing in Kuala Lumpur, Malaysia. This study's inclusion criteria include postpartum mothers aged 18 years or older who could comprehend the study protocol and provide informed consent. Postpartum women were approached in person at specialized postpartum care centres, community health facilities, and infant product exhibitions. Information about the study was disseminated through digital platforms, including Facebook and Instagram, as well as online forums dedicated to parenting and breastfeeding support. Additionally, enrolled participants facilitated further recruitment by referring acquaintances who were also new mothers. Participants were provided with a participant information sheet followed by a thorough explanation. All mothers granted their written informed consent before enrolling into the study. They completed a self-administered questionnaire that consisted of socio-demographic information (5 items), maternal and pregnancy characteristics (9 items), postpartum and infant characteristics (14 items), and MHM consumption (7 items). These questionnaires were adapted from previous studies investigating the use of herbal medicines during pregnancy and after childbirth [9, 10, 41, 42]. The study was conducted in accordance with ethical principles outlined in the Declaration of Helsinki, and received approval by the Malaysia Research Ethics Committee (MREC) with approval code NMRR-15-990-25727 on 22nd October, 2015.

2.2 Sample Collection and Extraction

The three most commonly consumed MHM throughout pregnancy and postpartum were identified using the questionnaire; Manjakani (*Quercus infectoria*), Nona Roguy and Halba (*Trigonella foenum-graecum*). To ensure a representative sample, one sample for each MHM was collected from every district in Kuala Lumpur, Malaysia, except for the Nona Roguy confinement set, which is available exclusively through a sole distributor in the country. Twenty-three samples were collected in sealed zip-lock bags and stored at 4 °C. All samples were rinsed with tap water, followed by deionised water. Then, they were oven-dried at 60 °C until constant weight. Dried samples were homogenised, powdered, and sieved through a 0.5 mm screen before being stored in sealed zip-lock bags until analysis.

In a Teflon tube, 0.5 g of powdered MHM samples were mixed with 5 mL of 65% nitric acid and 1 mL of 30% hydrogen peroxide. It was microwave-assisted digested with the heating program as follows: (1) 1000 W for 5 min at 80 °C, (2) 1000 W for 5 min at 50 °C, (3) 1000 W for 20 min at 190 °C, and (4) 0 W for 30 min [43]. After cooling, the solutions were diluted with distilled water to 50 mL. The NIST-1547 peach leaves (Merck, Germany) certified reference material was subjected to same experimental conditions as the MHM samples. Recovery values were within 92–101%, and the matrix effect was within 1–1.1%; both of which were within the acceptable range [44, 45]. All samples were analysed in triplicates to ensure precision and reproducibility of the results.

2.3 Toxic metal analysis

Inductively Coupled Mass Spectrometry (ICP-MS) was used to quantify heavy metals in MHM samples (Perkin Elmer, USA). Prior to the analysis of the samples, a seven-point calibration curve was produced for each metal ion, and these calibration curve correlation coefficients were always greater than 0.995 [46]. The method's Limit of Detections (LODs) for As, Cd, Pb, and Cr were 0.0414, 0.0126, 0.8304, and 0.7221 µg/kg, respectively. The method's repeatability was determined by measuring intra-day and inter-day precision, with the relative standard deviation for all repeated measurements being less than 10%, indicating the method was precise [47]. The method's precision, sensitivity, and accuracy were adequate for all analytes, as detailed in supplementary table S1. To monitor and minimize potential cross-contamination, a laboratory reagent blank was tested with each batch of samples. Additionally, 50 µg/kg of Rhodium was spiked into all samples and solutions as an internal standard to compensate for any loss during sample preparation and analysis.

2.4 Statistical analysis

The Statistical Package for the Social Sciences (SPSS) software version 20 (IBM, USA) was used for all statistical analyses. The Chi-square and Fisher's Exact tests examined the association between socio-demographics, maternal, pregnancy, infant, and postpartum characteristics across the different groups of mothers. The independent *t*-test determined mean age and weight differences between mothers' groups. Relative risk was utilised to compare the risk of pregnancy and birth outcomes among mothers' groups; values greater than 1 imply an increased risk of the outcome by the exposure. Results are statistically significant if $p < 0.05$ with a 95% confidence interval.

2.5 Human health risk assessments

Non-carcinogenic health risk for each heavy metal was determined using hazard quotient (HQ). The HQ is defined as the ratio of average daily dose (ADD) (mg/kg/day) to its oral reference dose (RfD) (mg/kg/day). RfD values were in accordance with the guidelines from the United States Environmental Protection Agency (US-EPA): 0.0008 mg/kg/day for As, 0.001 mg/kg/day for Cd, 1.5 mg/kg/day for Cr and Pb at 0.004 mg/kg/day for Pb [48, 49]. ADD was estimated using Eq. (1). HQ was calculated using Eq. (2).

$$ADD = \frac{C \times CR \times Ef \times Ed}{BW \times AT} \tag{1}$$

where C = Detected concentration of metal in food (mg/kg), CR = Consumption rate (kg/day), Ef = Exposure frequency (days/year), Ed = Exposure duration (years), BW = Body weight (kg), AT = Average exposure time (Ed × 365 days)

$$HQ = \frac{ADD}{RfD} \tag{2}$$

HQs of five heavy metals were summed up to obtain a non-carcinogenic 'Hazard Index (HI)' for each MHM as per Eq. (3). HQ > 1 and HI > 1 indicate significant non-carcinogenic health risks due to heavy metal exposure [49].

$$HI = \sum HQ \tag{3}$$

3 Results

3.1 Socio-demographics and maternal characteristics

Mothers who consumed MHM were slightly older than non-consuming mothers, ages 34.3 ± 4.5 years old compared to 33.9 ± 4.7 years old (Table 1). No association was found between MHM consumption and socio-demographic characteristics. However, a significant association ($p < 0.05$) was found between MHM consumption and the number of pregnancies and children. Mothers who consumed MHM had more previous pregnancies (85.7%) and children (84.5%) than non-consumers (69.9% and 68.7%, respectively). Among MHM consumers, most had three or more previous pregnancies (56.0%), followed by two or more previous pregnancies (29.8%) and one previous pregnancy (14.3%). Additionally, more than half (53.6%) of mothers who used MHM had three or more children, 31.0% had two children, and 15.5% had one child. A significant association ($p < 0.05$) was observed between MHM consumption and pre-pregnancy weight. Mothers who consumed MHM had a higher median pre-pregnancy weight (58.0 kg) than non-consumers (55.0 kg).

3.2 Pregnancy, postpartum and infant characteristics

A significant association ($p < 0.05$) was found between MHM consumption and a history of threatened abortion (Table 2). Threatened abortion was more prevalent among mothers who consumed MHM (27.4%) than non-consumers (13.3%). Additionally, MHM consumption was significantly associated ($p < 0.05$) with the diagnosis of chronic illness. Specifically, 7.1% of MHM consumers were diagnosed with chronic illnesses, whereas none of the non-consumers reported such diagnoses. Mothers consuming MHM were twice as likely to experience threatened abortion, with a relative risk of 2.066 (95% CI 1.077–3.963) (supplementary table S2). Meanwhile, the relative risk for mothers diagnosed with chronic illness could not be established due to the absence of any cases among non-MHM consumers.

3.3 Patterns and types of MHM use

Parents or parents-in-law were the primary sources of information concerning the use of MHM during pregnancy and postpartum ($n = 30$, 35.7%), followed by husbands, friends or siblings ($n = 18$, 21.4%), traditional medicine practitioners ($n = 17$, 20.2%), commercial advertisements ($n = 12$, 14.3%) and articles in health magazines ($n = 7$, 8.3%). Primary intentions for MHM consumption were to improve health and energy ($n = 57$, 67.9%), facilitate wound healing ($n = 32$, 38.1%), manage muscle and body aches ($n = 16$, 19.0%), slim down ($n = 12$, 14.3%) and increase breast milk

Table 1 Socio-demographics and maternal characteristics of MHM consumers and non-consumers

Socio-demographics and maternal characteristics	Consumers ($n = 84$)		Non-consumers ($n = 83$)		p-Value
	n	%	n	%	
Age (years), mean ± SD	34.3 ± 4.5		33.9 ± 4.7		0.569[a]
Occupation					
Housewife	26	31.0	25	30.1	0.402[b]
Private sector	18	21.4	25	30.1	
Government sector	40	47.6	33	39.8	
Level of education					
Tertiary level	35	41.7	45	54.2	0.105[b]
Secondary level or below	49	58.3	38	45.8	
Personal monthly income					
MYR5000 or less	73	86.9	66	79.5	0.201[b]
More than MYR5000	11	13.1	17	20.5	
Household monthly income					
MYR5000 or less	33	39.3	37	44.6	0.488[b]
More than MYR5000	51	60.7	46	55.4	
Number of previous pregnancies					
One	12	14.3	25	30.1	0.041[b]*
Two	25	29.8	23	27.7	
Three or more	47	56.0	35	42.2	
Number of children					
One	13	15.5	26	31.3	0.038[b]*
Two	26	31.0	25	30.1	
Three or more	47	53.6	32	38.6	
History of miscarriage	3	3.6	4	4.8	0.720[c]
Primary care-taking time					
Daytime	6	7.1	0	0	0.010[b]
Evening or night	18	21.4	11	13.3	
Whole day	60	71.4	72	86.7	
Not the primary caretaker	0	0	0	0	
Place of postpartum confinement					
Confinement center	3	3.6	1	1.2	0.620[b]
Home	81	96.4	82	98.8	
Breastfeeding	78	92.9	78	94.0	0.771[c]
Pre-pregnancy weight (kg), median (IQR)	58.0 (17.8)		55.0 (10.0)		0.036[d]*
Pregnancy weight (kg), mean ± SD	72.8 ± 12.2		71.2 ± 11.2		0.375[a]
Postpartum weight (kg), mean ± SD	62.6 ± 12.1		61.6 ± 10.9		0.569[a]

*Statistically significant at $p < 0.05$

[a] Analysed using Independent t-test

[b] Analysed using Chi-square test

[c] Analysed using Fisher's Exact test

[d] Analysed using Mann–Whitney U test

production ($n = 12$, 14.3%). MHM was purchased from local herbal stores ($n = 31$, 36.9%), online sellers ($n = 23$, 27.4%) and traditional medicine practitioners ($n = 17$, 20.2%). Most mothers who consumed MHM ($n = 73$, 86.9%) perceived MHM as "effective" and "brought desired effects".

The three most commonly consumed MHM were Manjakani ($n = 23$, 27.38%), Nona Roguy confinement set ($n = 22$, 26.19%), and Halba ($n = 22$, 26.19%) (supplementary figure S1). Detailed information on MHM ingredients and medicinal properties is provided in supplementary table S3. Other commonly consumed MHM were Ubat Periuk ($n = 21$,

Table 2 Pregnancy, postpartum and infant characteristics of MHM consumers and non-consumers

Pregnancy, infant and postpartum characteristics	Consumer ($n=84$)		Non-consumer ($n=83$)		p-Value
	n	%	n	%	
Threatened abortion	23	27.4	11	13.3	0.023[a]*
Pregnancy-related illness	17	20.2	11	13.3	0.227[a]
Diagnosed with chronic illness	6	7.1	0	0	0.028[b]*
Medication during pregnancy	4	4.8	1	1.2	0.367[b]
Caesarean delivery	19	22.6	22	26.5	0.560[a]
Preterm delivery	1	1.2	4	4.8	0.210[b]
Low birth weight	1	1.2	1	1.2	1.000[b]
Low birth length	0	0	0	0	NA[#]
Low head circumference	5	6.0	3	3.6	0.720[a]
Presence of jaundice	61	72.6	53	63.9	0.224[a]
Frequent episodes of colic	1	1.2	1	1.2	1.000[b]
Frequent episodes of crying at night	0	0	1	1.2	0.497[b]
Postpartum outpatient visit	2	2.4	1	1.2	1.000[b]
Medication during postpartum	2	2.4	2	2.4	1.000[b]

[#] Not applicable

[*] Statistically significant at $p < 0.05$

[a] Analysed using Chi-square test

[b] Analysed using Fisher's Exact test

25.0%), Minyak Kelapa ($n=15$, 17.86%), Akar Serapat ($n=7$, 8.33%), Afiat confinement set ($n=7$, 8.33%), Spirulina ($n=6$, 7.14%), and Sanggul Kacip Fatimah ($n=6$, 7.14%).

3.4 Heavy metal quantification in MHM

As, Cr and Pb were detected in Manjakani, Nona Roguy confinement sets and Halba samples (Fig. 1). Cd was detected in 63.6% of Manjakani samples, as well as all Nona Roguy confinement sets and Halba samples. The mean concentrations of As, Cd, Cr and Pb in MHM were 47.44 ± 67.74 µg/kg, 25.34 ± 2.48 µg/kg, 3685.87 ± 5683.36 µg/kg and 194.33 ± 195.19 µg/kg, respectively. Specifically, the mean concentrations of heavy metals in each MHM are as

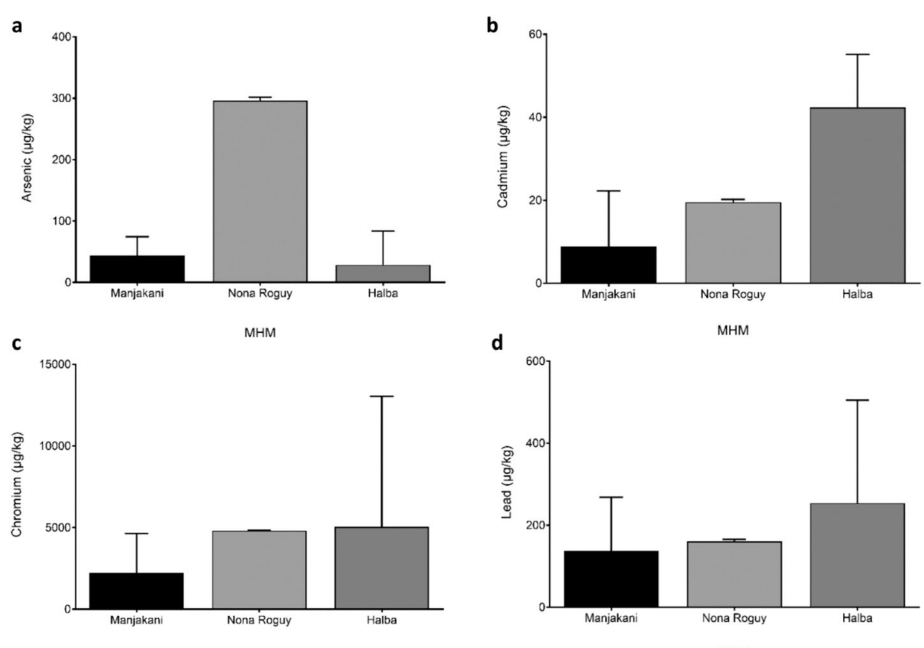

Fig. 1 Concentrations of heavy metals of **a** As, **b** Cd, **c** Cr and **d** Pb in MHM consumed during pregnancy and postpartum. Data are presented as mean ± SD

follows: 43.55 ± 29.32 μg/kg As, 13.90 ± 13.62 μg/kg Cd, 2223.75 ± 2299.87 μg/kg Cr and 137.47 ± 124.61 μg/kg Pb for Manjakani; 296.00 ± 5.66 μg/kg As, 19.50 ± 0.71 μg/kg Cd, 4817.50 ± 40.31 μg/kg Cr and 160.50 ± 4.95 μg/kg Pb for Nona Roguy confinement sets; 28.73 ± 52.47 μg/kg As, 42.36 ± 12.23 μg/kg Cd, 5045.13 ± 7625.38 μg/kg Cr and 254.27 ± 239.18 μg/kg Pb for Halba.

The highest concentrations of Cd, Cr and Pb were quantified in Halba samples, with concentrations of 77.00 ± 1.41 μg/kg, 28,883.50 ± 12.02 μg/kg and 947.00 ± 24.04 μg/kg, respectively. The highest As concentration was quantified in the Nona Roguy confinement set, measuring 296.00 ± 5.66 μg/kg.

3.5 Human risk assessments of heavy metals in MHM

The mean consumption rate (CR) was determined at 0.023 kg/day for Manjakani, 0.007 kg/day for Nona Roguy confinement set, and 0.006 kg/day for Halba, while mean exposure frequency (Ef) was calculated as 21 days/year, 22 days/year and 30 days/year for Manjakani, Nona Roguy confinement set and Halba, respectively. The maximum CR was determined to be 0.053 kg/day for Manjakani, 0.010 kg/day for Nona Roguy confinement set, and 0.015 kg/day for Halba; while EF was calculated as 100 days/year, 60 days/year and 90 days/year for Manjakani, Nona Roguy confinement set and Halba, respectively. An average mother's body weight (BW) of 72.8 kg was used for these calculations, while average exposure time (AT) was determined as 365 days.

Hazard quotients and hazard indexes for all heavy metals were calculated to be less than 1 (HQ < 1 and HI < 1) (Table 3). The HQs for heavy metals were ranked in descending order of As > Pb > Cd > Cr. Given HQ < 1 and HI < 1, no significant non-carcinogenic health risks associated with As, Cd, Cr and Pb contamination in the three most commonly consumed MHM during pregnancy and postpartum.

3.6 Risk assessment for individual mothers

Additionally, individual hazard quotients were calculated based on each mother's consumption rate (CR), exposure frequency (Ef) and body weight (BW). Mean and maximum hazard quotients (HQ_{mean} or HQ_{max}) were calculated using the mean or the highest concentration of As, Cd, Cr and Pb in each MHM sample.

Individual HQ_{mean}, HQ_{max} and HI_{mean} for all metals were calculated and found to be less than 1 (HQ < 1; HI_{mean} < 1). Alarmingly, two mothers have HI_{max} > 1 being 1.35 and 2.52; the HI_{max} was calculated based on the maximum quantified heavy metal concentration. The mother with the highest HI of 2.52 had a relatively low body weight of 55 kg and a high consumption rate of Manjakani, consuming 50 g per intake for 60 days postpartum. Individual HI_{max} > 1 indicated a significant non-carcinogenic health risk with the possibility of adverse health effects due to heavy metal contamination. These findings indicate that, under worse-case scenarios involving high heavy metal contamination, a high consumption rate, and lower body weight, there is a potential for significant non-carcinogenic health risks and adverse health effects. This highlights the importance of considering individual variations and consumption patterns when assessing health risks related to heavy metal exposure from MHM.

Table 3 Health risk assessments for exposure of As, Cd, Cr and Pb in MHM

MHM	HQ_{mean}				HQ_{max}				HI_{mean}	HI_{max}
	As	Pb	Cd	Cr	As	Pb	Cd	Cr		
Manjakani	0.0012	0.0008	0.0001	0.00001	0.0417	0.0296	0.0155	0.00120	0.002	0.093
Nona Roguy confinement set	0.0020	0.0002	0.0001	0.00002	0.0143	0.0016	0.0008	0.00177	0.002	0.017
Halba	0.0001	0.0003	0.0003	0.00001	0.0211	0.0206	0.0067	0.00012	0.001	0.050

HQ hazard quotient; *HI* hazard index

4 Discussion

This study investigated the differences in socio-demographics, pregnancy and birth outcomes, and postpartum features between MHM consumers and non-consumers. Furthermore, it quantified heavy metal contamination in the three most commonly consumed MHM and assessed the associated health risks of their use during pregnancy and the postpartum period.

Previous studies have reported varied patterns and motivations for herbal medicine use across different regional communities [50–52]. In Malaysia, socio-demographics such as ethnicity, age, education, and income are influencing factors for using traditional remedies [5, 53]. In England, multiparous mothers favoured the use of herbal medicine during pregnancy [54]; whereas in Australia, primiparous mothers showed a higher preference for herbal remedies [55]. This study found that MHM was predominantly consumed by multiparous Malay mothers with higher pre-pregnancy body weight. These findings were consistent with a Malaysian study that observed frequent herbal medicine use among mothers of two or more children [39]. Another study hypothesised first-time mothers are less likely to use herbal medicine during pregnancy [56]. Additionally, mothers with a history of herbal medicine consumption tend to use it more frequently [57]. In our study, mothers who consumed MHM consistently had higher body weights throughout pre-pregnancy, pregnancy and post-pregnancy. It is postulated that heavier mothers might be more inclined to consume MHM as part of their efforts to reduce or maintain body weight; 14.3% of them indicated slimming down as their goal and reason for MHM use [10]. A common belief among Malaysians is that herbal remedies are free from hazardous chemicals and are considered safer alternatives to conventional modern medicine [58, 59].

Mothers who consumed MHM had higher incidences of threatened abortions and chronic illnesses compared to non-consuming mothers. In contrast, other studies have reported no significant association between the use of Chinese herbal medicine and abortion outcomes [60, 61]. The observed significant associations between MHM consumption and both threatened abortion and chronic illnesses may not imply causative effects. Rather, these findings may be influenced by reverse causative effects, where mothers with history of threatened abortion or chronic illnesses may use MHM in hopes for a healthier pregnancy and better birth outcomes. Previous research has shown that individuals with chronic conditions frequently use herbal medicine worldwide, often seeking long-term health benefits, improved well-being, and treatment for acute diseases [51, 62, 63]. This pattern suggests that the use of MHM among mothers with pre-existing conditions might be a proactive measure rather than a direct cause of adverse outcomes. Nevertheless, these findings underscore the need for future research to revalidate the relationship between herbal medicine use, threatened abortion and chronic illnesses.

The Malaysian Drug Control Authority has established permissible levels of heavy metals for Pb, As and Cd in herbal medicine to be less than 10, 5, and 0.3 mg/kg, respectively [64]. These regulatory reference values are comparable to the World Health Organization (WHO) and other nations' standards for permissible levels of heavy metals in the human diet. Notwithstanding, these seemingly stringent, safe and acceptable levels provide misleading propositions on the safety profile of herbal consumption during pregnancy. Fetus are particularly vulnerable to heavy metal toxicity due to their lighter body weight, rapid phase of growth and development, and their limited capacity to eliminate heavy metals from their system [65–67]. The Joint FAO/WHO Expert Committee on Meals Additives (JECFA) has since withdrawn tolerable intake for Pb and As, citing the absence of safe levels and emphasizing the critical need to limit heavy metals in children's food [68]. Pb is highly neurotoxic, even at extremely low concentrations, eliciting adverse effects on cognitive function in children [69]. Epidemiological studies have linked As exposure in young children to cutaneous, neurological, and gastrointestinal problems [70]. Chronic exposure to Cd, which has a long biological half-life of 10–30 years in the kidneys, can lead to long-term health consequences [71]. Cd exposure during pregnancy and early childhood may affect the thyroid, growth hormone, and estrogen systems [72, 73]. It can also adversely affect the normal development of critical organs, particularly the nervous system during intrauterine life. Additionally, the accumulation of Cd in the placenta may impede the delivery of other trace elements (Fe, Mn, Zn, Mo, and Cu) to the fetus [74, 75]. Its effects can be deleterious as Zn and Fe are essential metals for brain formation and other developmental processes [71].

A study in Romania reported a combined HQ > 1 for parsley, carrot roots, cabbage, and lettuce, despite individual HQ for each metal being within safe limits [76]. This suggests that the cumulative effects of consuming multiple herbs simultaneously can pose significant health risks. In this study, the HI for all investigated MHM was within the safe range. The health risk assessment was limited to the top three MHM and the concentrations of four heavy metals. Consequently, these results may not fully capture the broader risks associated with heavy metal toxicity. Heavy metals can accumulate in the body, so their health risks may increase with prolonged consumption and repeated exposures across multiple pregnancies [77]. These findings underscore the need for further research to assess the impact of all types of toxic metal exposure on both mothers and children, and to explore modifiable factors, such as, dietary intake to understand better the risks to both the foetus and the mother.

To the best of our knowledge, this study is the first to investigate potential heavy metal contamination in MHM consumed during pregnancy and postpartum, as well as, the associated health risks. As a pilot study, it was exploratory and aimed at investigating preliminary concerns. Postpartum mothers are known to be a vulnerable group, particularly concerning mental health disorders, such as, maternal postpartum depression [78]. Although there is no universally established sample size for pilot studies, calculations suggest that a minimum of 59 participants per arm is required to identify problems with a 5% probability and a 95% confidence interval [79]. To ensure recruitment and participation's feasibility and logistical viability, we opted for a smaller sample size while not compromising the detection of potential issues. The findings of this pilot study will inform the design of future, larger-scale studies aimed at accurately assessing the risks of heavy metal contamination in MHM during pregnancy and breastfeeding. The study underscores the need for more extensive longitudinal research involving larger populations. Given that MHM consumption is predominantly among a specific ethnic group in Malaysia and contamination was detected in all major MHM, the findings may not be fully representative of the broader population.

5 Conclusion

In summary, MHM use was predominantly favoured by multiparous mothers and those with higher pre-pregnancy body weight. MHM consumers exhibited a 106% increased risk of threatened abortion. The most commonly used MHM were Manjakani, Nona Roguy confinement set, and Halba. While all MHM samples were found to be contaminated with heavy metals, their concentrations remained below the government's permissible limits. Although no significant non-carcinogenic health risks were identified, the presence of heavy metals in MHM and their potential transfer from mother to fetus and infant raise concerns about safety during pregnancy and the postpartum period. This pilot study highlights the need for further longitudinal cohort research to examine the impact of heavy metals from MHM on infant growth and development over time. The findings serve as a crucial reference for MHM consumers and policymakers, providing essential safety information and guiding future research.

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Data availability All data generated or analysed during this study are included in this published article (and its Supplementary Information files).

Declarations

Ethical statement The study was conducted in accordance with the Declaration of Helsinki, and approved by the Malaysia Research Ethics Committee (MREC) via approval code NMRR-15-990-25727 on 22nd Oct, 2015.

Informed consent statement Informed consent was obtained from all subjects involved in the study.

Consent for publication Not applicable.

Competing interests Authors declare no competing interests.

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