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Original article

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Impaired fetal growth and preterm birth are the leading causes of neonatal and infant mortality worldwide and there is a growing scientific literature suggesting that environmental exposures during pregnancy may play a causal role in these outcomes. Our purpose was to assess the environmental exposure of the Fetal Growth Longitudinal Study (FGLS) participants in the multinational INTERGROWTH-21st Project. First, we developed a tool that could be used internationally to screen pregnant women for such exposures and administered it in eight countries on a subsample (n = 987) of the FGLS participants. The FGLS is a study of fetal growth among healthy pregnant women living in relatively affluent areas, at low risk of adverse pregnancy outcomes and environmental exposures. We confirmed that most women were not exposed to major environmental hazards that could affect pregnancy outcomes according to the protocol's entry criteria. However, the instrument was able to identify some women that reported various environmental concerns in their homes such as peeling paint, high residential density (>1 person per room), presence of rodents or cockroaches (hence the use of pesticides), noise pollution and safety concerns. This screening tool was therefore useful for the purposes of the project and can be used to ascertain environmental exposures in studies in which the primary aim is not focused on environmental exposures. The instrument can be used to identify subpopulations for more in-depth assessment, (e.g. environmental and biological laboratory markers) to pinpoint areas requiring education, intervention or policy change.

Keywords Environmental exposure, exposure questionnaire, fetal exposure, fetal growth, low birth weight, maternal exposure, pregnancy, preterm.

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Introduction

Impaired fetal growth and preterm birth are the leading causes of neonatal and infant mortality worldwide.[1] Previous studies have linked these fetal endpoints to exposures such as environmental tobacco smoke,[2] heavy metals,[3] air pollution,[4] pesticides,[5] water pollution[6] and occupation-related hazards[7] and it is likely that most pregnant women are exposed to multiple pollutants in the environment. Moreover, some toxins persist and bio-accumulate while others have acute effects. Various chemicals may have interactive and synergistic effects on the health of the pregnant woman and fetus.

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There are numerous challenges in assessing exposures to pregnant women, including the availability and sensitivity of laboratory analyses, the pharmacokinetics of individual chemicals (such as short half-life or fat solubility), the changing pharmacokinetics during pregnancy and the cost of chemical analyses, to name a few.[8] In addition, if the effects of specific chemical exposures are not the main focus of study, but merely potential confounders, their measurement may be beyond the scope and budget of the research.

We explore the utility of a brief questionnaire to screen for substantive environmental exposures of healthy pregnant women at low risk for high exposure to environmental toxicants, population characteristics required by the study protocol of the Fetal Growth Longitudinal Study (FGLS) component of the INTERGROWTH-21st Project.[9] The aim was to characterise the overall environmental exposures of the women enrolled in FGLS in eight geographically diverse regions: Pelotas, Brazil; Beijing, China; Nagpur, India; Turin, Italy; Nairobi, Kenya; Muscat, Oman; Oxford, UK and Seattle, USA.

Methods

Participants

Women in the present study are a subset of participants from the INTERGROWTH-21st FGLS from the eight study sites selected with the intention of achieving geographical distribution across continents. Geographical areas with severe pollution, high altitude, domestic smoke, radiation or any other known sources of toxic substances were not eligible. Women in this substudy were enrolled between April 2011 and November 2012.

Within each geographical area, all medical institutions where deliveries took place were enumerated and those with >1000 deliveries per year that primarily served low-risk populations were eligible (i.e. low-birthweight rate <10%, altitude <1600 m, perinatal mortality <20 per 1000 live births, antenatal care and delivery in the same institution or in a similar hospital nearby, and >75% of mothers with adequate education, as defined locally). The selected institutions covered >75% of all deliveries in the regions.

Within each study site, individual women were eligible for FGLS if they attended their first antenatal visit in the selected institutions and were <14 weeks of gestation by menstrual dates, 18 to <35 years old, nonsmokers and low consumers of alcohol. Among other criteria constituting a healthy medical history, women were eligible if they had a singleton pregnancy, a body mass index between 18.5 and <30 kg/m^2, height ≥153 cm, plus no previous history of sexually transmitted diseases, a low-birthweight or preterm infant, or pre-eclampsia or a hypertensive disorder. In addition, the women could not have an occupation that was very physically demanding or with a high risk of exposure to chemicals or toxic substances. Hence, this group was, in principle, at low risk of high environmental exposure. A detailed description of the FGLS population, individual entry criteria and methodology has been presented elsewhere.[9]

For this substudy, we were required by the project's protocol to explore the: 'absence of known nonmicrobiological contamination such as pollution, domestic smoke, radiation or any other toxic substances, evaluated at the cluster level using a data collection form specifically developed for the project'. We aimed to include ~125 women from each of the eight sites for a total of 1000 women. We approached all women enrolled in FGLS consecutively, regardless of gestational age, over the period required to reach the required target sample. The length of this period varied according to the number of women attending each centre. We succeeded in interviewing a total of 987 women (Brazil 124, China 102, India 124, Italy 125, Kenya 124, Oman 125, UK 126 and USA 137). They represent 21.9% of the total target sample of FGLS (4500 women).

In addition, all women in FGLS were questioned at every antenatal visit on whether they had engaged, since the previous visit, in any of the high-risk occupations identified as exclusion criteria for the study, started smoking or used recreational drugs. These results are also presented here.

Questionnaire development

The Maternal Environmental Assessment (MEA) form of the INTERGROWTH-21st Project is an instrument produced specifically for FGLS and is based on the previous experience of the research group members and published surveys. It is composed of questions that aim to ascertain exposure to environmental factors known or suspected to affect the health of the fetus or pregnant woman. Specific questions targeting selected exposures were drawn from several previously validated, pregnancy-related environmental surveys by the Center for Environmental Research and Children's Health (CERCH) of the University of California, Berkeley School of Public Health.[10,11] The questions were selected to complement but not to duplicate questions, i.e. demographic or educational, included in other FGLS questionnaires. Therefore, we did not include questions, for example, on maternal smoking or drug use during the index pregnancy. After consultation with local investigators, an advisory board of reproductive epidemiologists from various countries, and members of the Children's Environmental Health group within the International Programme of Chemical Safety of World Health Organization's Department of Public Health and Environment, we developed an initial version of the questionnaire. We piloted the initial draft at three study sites (Brazil, Kenya and UK) and then, with our Advisory Board of reproductive epidemiologists,

refined the survey to assess exposures better within the cultural contexts. The final data collection form was translated into the predominant languages of the women enrolled in each of the eight FGLS sites.

The MEA includes a total of 123 questions comprising a five-page paper questionnaire and took 10–15minutes to complete. It is composed of two sections to assess: (1) the home environment and (2) conditions of work and other environments. The first section includes 66 questions that ask about housing and neighbourhood characteristics (housing materials, sanitary services, electricity, cooking materials, heating, smokiness, use of food in plastic/cans, drinking water source, housekeeping habits, use of air fresheners and candles, respiratory allergens such as cockroaches, mould etc., exposure to environmental tobacco smoke, pesticide use in and around the home, nearby traffic density, ambient air pollution, neighbourhood safety). The second section includes 57 questions that ascertain environmental conditions in the workplace, including occupational characteristics, occupation-specific hazards and toxin exposure, and indoor air pollution and other workplace characteristics.

Questionnaire pilot

Interviews were conducted in antenatal clinics; women could be accompanied by their partners, family members, and/or friends who were allowed to contribute to the descriptions. The information was collected in the local language via an interviewer to maintain reporting consistency.

Statistical analysis

The aim of this specific component of the INTERGROWTH-21st Project was to develop a questionnaire that could assess the range of environmental exposures among healthy pregnant women across eight different countries on five continents, but who share living in urban areas with relatively low exposures. For this investigation, the questionnaire was not intended to relate exposure to individual pregnancy outcomes. We present the frequency of responses to each question by study site and for the total sample. Where responses were infrequent, we collapsed responses. We noted qualitative differences among sites.

The Ethics Committees of the participating centres approved this component of the project. Written consent, over and above the informed consent obtained for FGLS, was not required for this component of the study.

Results

Home characteristics

As shown in Table 1, the majority of women lived either in independent detached houses (39.6%) or in buildings with three or more apartments (33.3%). About half of the women lived in dwellings with four or more rooms. Overall, only 11.3% of women lived in houses with more than one person/room in which they slept or lived,[12] with the highest such proportion in India (45.9%). Almost all women had electricity in their homes (99.4%). Floors were constructed of hard surfaces, namely, wood, tiles or cement, in nearly all homes (78.1%) and most had roofs of concrete or tiles (83.7%).

Almost all homes had a toilet with a water supply in the house (98.1%). Most had stoves heated by electricity or gas (98.9%); gas stoves were most commonly used in Brazil, India, Kenya and Oman (>88%). Nearly all homes (>95%) in China, Italy, UK and USA, regions with temperatures that require it, had heating systems; two-thirds of homes had heat in Brazil. Most women in China, India, UK and USA drank tap water. However, in China all women reported boiling the water and about half boiled the water in India and Kenya. In Brazil, Italy and Oman, more than half drank bottled water. Cleaning the house, including sweeping or vacuuming, was done weekly or more often in nearly all households (91.6%). So, the women in this cohort tended to live in well-maintained clean housing stock with electricity, cooking facilities, safe water and sanitary facilities.

Home exposures

Less than 10% of homes overall were reported to have some water damage during periods of rainfall, musty or mouldy odour, or mice or rats. The reporting of having seen or been aware of rodents in the home was common and as high as 29.8% in India. Overall, 17.8% of women reported having seen cockroaches, reaching 39.5% in India and 54.8% in Kenya (Table 2).

About 14% of women reported peeling paint on the walls and windowsills, with nearly a third of homes reported as having some peeling paint in Brazil. A quarter of women during pregnancy, with >35% in Brazil, India and Kenya, reported that pesticides were used to kill or repel mosquitos, garden bugs, rats or weeds around their homes or on their pets. However, overall, only 7.1% used the pesticides themselves during pregnancy, although this was nearly a quarter of participants in Kenya. Few women spent one or more hours a day near a person who smoked (~6%), with the highest proportion in Brazil (12.8%) and China (11.8%). (All women were nonsmokers as per protocol and only a small number took up smoking during pregnancy; they were excluded from the cohort.)

Neighbourhood characteristics

Table 3 shows the neighbourhood characteristics as reported by the women. Significant exposures were reported infrequently: <1% reported that their home was close to a chemical dumping site and 2.4% to a factory

Table 1. Description of housing characteristics for 987 pregnant women by study site in eight countries, FGLS, 2011–12

	Brazil *n* = 124 (%)	China *n* = 102 (%)	India *n* = 124 (%)	Italy *n* = 125 (%)	Kenya *n* = 124 (%)	Oman *n* = 125 (%)	UK *n* = 126 (%)	USA *n* = 137 (%)	Total *n* = 987 (%)
Home description									
Independent/ detached house	72 (58.1)	29 (28.4)	96 (77.4)	14 (11.2)	19 (15.3)	61 (48.8)	16 (12.7)	84 (61.3)	391 (39.6)
Attached house	13 (10.5)	32 (31.4)	6 (4.8)	39 (31.2)	19 (15.3)	32 (25.6)	89 (70.7)	21 (15.3)	251 (25.4)
Apartment building	39 (31.5)	40 (39.2)	11 (8.9)	72 (57.6)	84 (67.7)	32 (25.6)	20 (15.9)	31 (22.6)	329 (33.3)
Other	–	1 (1.0)	11 (8.9)	–	2 (1.6)	–	1 (0.8)	1 (0.7)	16 (1.6)
Home density (people/room)									
≤0.50	70 (56.5)	37 (36.3)	10 (8.1)	19 (15.2)	64 (51.6)	33 (26.4)	82 (65.1)	73 (53.3)	388 (39.3)
0.51–1.0	49 (39.5)	55 (53.9)	57 (46.0)	100 (80.0)	54 (43.5)	71 (56.8)	43 (34.1)	58 (42.3)	487 (49.3)
>1.0	5 (4.0)	10 (9.8)	57 (45.9)	6 (4.8)	6 (4.8)	21 (16.8)	1 (0.8)	6 (4.4)	112 (11.3)
Floor covering									
Carpet/rug	6 (4.8)	–	3 (2.4)	1 (0.8)	5 (4.0)	13 (10.4)	90 (71.4)	82 (59.9)	200 (20.3)
Hard surface (wood, tile, cement)	113 (91.1)	102 (100.0)	121 (97.5)	123 (98.4)	114 (92.0)	112 (89.6)	35 (27.8)	51 (37.3)	771 (78.1)
Other	5 (4.0)	–	–	1 (0.8)	5 (4.0)	–	1 (0.8)	4 (2.9)	16 (1.6)
Stove									
No	2 (1.6)	29 (28.4)	11 (8.9)	3 (2.4)	–	–	2 (1.6)	–	47 (4.8)
Yes	122 (98.4)	73 (71.6)	113 (91.1)	122 (97.6)	124 (100.0)	125 (100.0)	124 (98.4)	137 (100.0)	940 (95.2)
Stove heating source									
Gas	120 (97.6)	7 (7.5)	121 (97.6)	82 (63.6)	122 (88.4)	113 (90.4)	63 (48.8)	49 (34.8)	677 (67.6)
Electricity	3 (2.4)	86 (92.5)	–	43 (33.3)	13 (9.4)	12 (9.6)	65 (50.4)	92 (65.2)	314 (31.3)
Heat home									
No	42 (33.9)	1 (1.0)	124 (100.0)	4 (3.2)	124 (100.0)	125 (100.0)	1 (0.8)	3 (2.2)	424 (43.0)
Yes	82 (66.1)	101 (99.0)	–	121 (96.8)	–	–	125 (99.2)	134 (97.8)	563 (57.0)
Home heating sources									
Gas	2 (2.4)	61 (59.8)	–	124 (94.7)	–	–	101 (79.5)	66 (48.9)	354 (61.2)
Electricity	66 (79.5)	4 (3.9)	–	1 (0.8)	–	–	18 (14.2)	64 (47.4)	153 (26.5)
Wood, charcoal, kerosene, crop waste	15 (18.1)	37 (36.3)	–	6 (4.6)	–	–	8 (6.3)	5 (3.7)	71 (12.3)
Drinking water source									
Tap water at home	45 (36.6)	89 (87.3)	114 (91.2)	29 (22.8)	72 (50.0)	19 (15.1)	114 (89.8)	119 (86.9)	601 (59.4)
Bottled water	63 (51.2)	13 (12.7)	1 (0.8)	96 (75.6)	58 (40.3)	105 (83.3)	13 (10.2)	16 (11.7)	365 (36.1)
Other	15 (12.1)	–	10 (8.0)	2 (1.6)	14 (9.7)	2 (1.6)	–	2 (1.4)	45 (4.5)
Sweep or vacuum home									
<1 time/week	5 (4.0)	–	4 (3.2)	13 (10.4)	1 (0.8)	–	18 (14.3)	42 (30.7)	83 (8.4)
1–6 time/week	62 (50.0)	84 (82.4)	1 (0.8)	85 (68.0)	64 (51.7)	40 (32.0)	96 (76.2)	80 (58.4)	512 (51.9)
Daily	57 (46.0)	18 (17.6)	119 (96.0)	27 (21.6)	59 (47.6)	85 (68.0)	12 (9.5)	15 (10.9)	392 (39.7)

Stove heating source: The number of women (991) given in this section exceeds the total number of women interviewed (987) and those reporting having a stove (940) because some women reported having two sources of heating (gas and electric).

emitting fumes or smoke (data not shown). Few women reported that the air was 'at least sometimes' difficult to breathe (<4%) or made their eyes sting (2.7%).

As expected in these urban areas, over 40% of the women lived near major roads with >40% in India, Kenya, Oman and UK. A total of 15.9% of women lived close to an agricultural field with a quarter in Oman and half in the UK.

Some neighbourhood nuisances were reported by >20% of women: for example, concerns about safety to walk alone at night were reported by women in Brazil, Italy, Kenya and Oman; dogs barking at night in Brazil, Italy and Kenya, and loud music/noise in Italy and Kenya. In China, UK and USA, all concerns were reported by <20% of the women (Table 3).

Work environment

Overall, two-thirds of women worked during their pregnancy but this proportion showed considerable variation

Table 2. Potential environmental hazards inside the homes of 987 pregnant women by study site, FGLS, 2011–12

	Brazil *n* = 124 (%)	China *n* = 102 (%)	India *n* = 124 (%)	Italy *n* = 125 (%)	Kenya *n* = 124 (%)	Oman *n* = 125 (%)	UK *n* = 126 (%)	USA *n* = 137 (%)	Total *n* = 987 (%)
Smoky kitchen when cooking									
No	123 (99.2)	97 (95.1)	101 (81.5)	116 (92.8)	124 (100.0)	124 (99.2)	112 (88.9)	134 (97.8)	931 (94.3)
Yes	1 (0.8)	5 (4.9)	23 (18.5)	9 (7.2)	–	1 (0.8)	14 (11.1)	3 (2.2)	56 (5.7)
Boil water									
No	115 (92.7)	–	68 (54.8)	124 (99.2)	59 (47.6)	125 (100.0)	123 (97.6)	132 (96.4)	746 (75.6)
Yes	9 (7.3)	102 (100.0)	56 (45.2)	1 (0.8)	65 (52.4)	–	3 (2.4)	5 (3.6)	241 (24.4)
Mould/mildew on walls and other surfaces									
No	88 (71.0)	101 (99.0)	120 (96.8)	117 (93.6)	118 (95.2)	113 (90.4)	97 (77.0)	119 (86.9)	873 (88.4)
Yes	36 (29.0)	1 (1.0)	4 (3.2)	8 (6.4)	6 (4.8)	12 (9.6)	29 (23.0)	18 (13.1)	114 (11.6)
Home water damage									
No	117 (94.4)	100 (98.0)	116 (93.5)	113 (90.4)	107 (86.3)	116 (92.8)	113 (89.7)	130 (94.9)	912 (92.4)
Yes	7 (5.6)	2 (2.0)	8 (6.5)	12 (9.6)	17 (13.7)	9 (7.2)	13 (10.3)	7 (5.1)	75 (7.6)
Musty/mouldy odour in home									
No	107 (86.3)	101 (99.0)	121 (97.6)	121 (96.8)	120 (96.8)	120 (96.0)	121 (96.0)	134 (97.8)	945 (95.7)
Yes	17 (13.7)	1 (1.0)	3 (2.4)	4 (3.2)	4 (3.2)	5 (4.0)	5 (4.0)	3 (2.2)	42 (4.3)
Peeling paint on walls and sills of home									
No	83 (67.5)	93 (91.2)	114 (91.9)	114 (91.2)	102 (82.3)	113 (90.4)	103 (81.7)	125 (91.2)	847 (85.9)
Yes	40 (32.5)	9 (8.8)	10 (8.0)	11 (8.8)	22 (17.7)	12 (9.6)	23 (18.3)	12 (8.7)	139 (14.1)
Mice or rats in home									
No	122 (98.4)	102 (100.0)	87 (70.2)	125 (100.0)	106 (85.5)	116 (92.8)	124 (98.4)	135 (98.5)	917 (92.9)
Yes	2 (1.6)	–	37 (29.8)	–	18 (14.5)	9 (7.2)	2 (1.6)	2 (1.5)	70 (7.1)
Cockroaches in home									
No	111 (89.5)	94 (92.2)	75 (60.5)	117 (93.6)	56 (45.2)	95 (76.0)	126 (100.0)	137 (100.0)	811 (82.2)
Yes	13 (10.5)	8 (7.8)	49 (39.5)	8 (6.4)	68 (54.8)	30 (24.0)	–	–	176 (17.8)
Hours per day around someone smoking									
0 hours	108 (87.1)	90 (88.2)	121 (97.6)	116 (92.8)	124 (100.0)	119 (95.2)	118 (93.7)	136 (99.3)	932 (94.4)
1+ hours	16 (12.8)	12 (11.8)	3 (2.4)	9 (7.2)	–	6 (4.8)	8 (6.4)	1 (0.7)	55 (5.5)
Cats/dogs in home									
No	55 (44.4)	86 (84.3)	115 (92.7)	80 (64.0)	120 (96.8)	121 (96.8)	83 (65.9)	59 (43.1)	719 (72.8)
Yes	69 (55.6)	16 (15.6)	9 (7.3)	45 (36.0)	4 (3.2)	4 (3.2)	43 (34.1)	78 (57.0)	268 (27.2)
Pesticides applied in/around home/pets									
No or don't know	79 (63.7)	99 (97)	79 (63.7)	94 (75.2)	69 (55.6)	106 (84.8)	105 (83.3)	113 (82.4)	744 (75.4)
Yes	45 (36.3)	3 (2.9)	45 (36.3)	31 (24.8)	55 (44.4)	19 (15.2)	21 (16.7)	24 (17.5)	243 (24.6)
Personal application of pesticides									
No or don't know	118 (95.2)	102 (100.0)	115 (92.7)	117 (93.6)	95 (76.6)	125 (100.0)	118 (93.7)	127 (92.7)	917 (92.9)
Yes	6 (4.8)	–	9 (7.3)	8 (6.4)	29 (23.4)	–	8 (6.3)	10 (7.3)	70 (7.1)

from 14.5% in India to 90.5% in the UK (Table 4); 14.1% believed they had done potentially hazardous activities when at work. Among women who worked, the majority worked between 31 and 40 hours/week.

Women worked in a variety of jobs; most common were jobs in healthcare institutions (46.8%), science laboratories (17.6%), mostly in the UK and USA, and hair salons (8.4%). A proportion of 21.8% of women reported that during pregnancy they had worked in a potentially hazardous business or industry, mostly in healthcare institutions and science laboratories (Table 5).

Approximately 17% of women reported handling chemicals, (cleaning or laboratory chemicals) or pharmaceutical drugs during their pregnancy with more than a quarter of women in Brazil, UK and USA reporting such exposure (Table 6).

Some women reported that their work environment was too hot (13.7%) or too cold (9.0%), too noisy (15.6%), dusty (9.4%) or poorly ventilated (10.9%; Table 4). Of note, 38.7% of women in Brazil said their work environment was too loud. The most common symptom reported in all countries was headache (42.9% of those women with less than ideal working conditions, data not shown).

Finally, data obtained at every antenatal care visit (using the same question format as in the survey) from the entire cohort of women enrolled in FGLS (up to the time of the

Table 3. Environmental hazards and nuisances outside the homes of 987 pregnant women by study site, FGLS, 2011–12

	Brazil *n* = 124 (%)	China *n* = 102 (%)	India *n* = 124 (%)	Italy *n* = 125 (%)	Kenya *n* = 124 (%)	Oman *n* = 125 (%)	UK *n* = 126 (%)	USA *n* = 137 (%)	Total *n* = 987 (%)
Air makes it difficult to breathe									
Never	118 (95.2)	102 (100.0)	118 (95.2)	118 (94.4)	116 (93.5)	114 (91.2)	125 (99.2)	137 (100.0)	948 (96.0)
At least sometimes	6 (4.8)	–	6 (4.8)	7 (5.6)	8 (6.5)	11 (8.8)	1 (0.8)	–	39 (4.0)
Air makes your eyes sting									
Never	121 (97.6)	102 (100.0)	122 (98.4)	112 (89.6)	124 (100.0)	120 (96.0)	122 (96.8)	137 (100.0)	960 (97.3)
At least sometimes	3 (2.4)	–	2 (1.6)	13 (10.4)	–	5 (4.0)	4 (3.2)	–	27 (2.7)
Home near an agricultural field									
No or don't know	117 (94.4)	97 (95.1)	116 (93.5)	108 (86.4)	107 (86.3)	92 (73.6)	60 (47.6)	133 (97.1)	830 (84.1)
Yes	7 (5.6)	5 (4.9)	8 (6.5)	17 (13.6)	17 (13.7)	33 (26.4)	66 (52.4)	4 (2.9)	157 (15.9)
Home near major road									
No or don't know	95 (76.6)	94 (92.2)	68 (54.8)	102 (81.6)	68 (54.8)	11 (8.8)	49 (38.9)	85 (62.0)	572 (58.0)
Yes	29 (23.4)	8 (7.8)	56 (45.2)	23 (18.4)	56 (45.2)	114 (91.2)	77 (61.1)	52 (38.0)	415 (42.0)
Loud music or other noise									
No	102 (82.3)	101 (99.0)	107 (86.3)	85 (68.0)	92 (74.2)	102 (81.6)	116 (92.1)	125 (91.2)	830 (84.1)
Yes	22 (17.7)	1 (1.0)	17 (13.7)	40 (32.0)	32 (25.8)	23 (18.4)	10 (7.9)	12 (8.8)	157 (15.9)
Rubbish/trash and litter on streets									
No	109 (87.9)	102 (100.0)	115 (92.7)	112 (89.6)	104 (83.9)	112 (89.6)	119 (94.4)	130 (94.9)	903 (91.5)
Yes	15 (12.1)	–	9 (7.3)	13 (10.4)	20 (16.1)	13 (10.4)	7 (5.6)	7 (5.1)	84 (8.5)
People using or selling drugs									
No	107 (86.3)	102 (100.0)	121 (97.6)	111 (88.8)	122 (98.4)	124 (99.2)	119 (94.4)	128 (93.4)	934 (94.6)
Yes	17 (13.7)	–	3 (2.4)	14 (11.2)	2 (1.6)	1 (0.8)	7 (5.6)	9 (6.6)	53 (5.4)
Crime, such as robberies or assault									
No	104 (83.9)	102 (100.0)	121 (97.6)	108 (86.4)	99 (79.8)	122 (97.6)	118 (93.7)	117 (85.4)	891 (90.3)
Yes	20 (16.1)	–	3 (2.4)	17 (13.6)	25 (20.1)	3 (2.4)	8 (6.3)	20 (14.6)	96 (9.7)
No safe place for children to play									
No	96 (77.4)	102 (100.0)	117 (94.4)	105 (84.0)	109 (87.9)	67 (53.6)	124 (98.4)	135 (98.5)	855 (86.6)
Yes	28 (22.5)	–	7 (5.6)	20 (16.0)	15 (12.1)	58 (46.4)	2 (1.6)	2 (1.4)	132 (13.4)
Not safe to walk alone at night									
No	79 (63.7)	102 (100.0)	119 (96.0)	89 (71.2)	80 (64.5)	65 (52.0)	118 (93.7)	121 (88.3)	773 (78.3)
Yes	45 (36.3)	–	5 (4.0)	36 (28.8)	44 (35.5)	60 (48.0)	8 (6.3)	16 (11.7)	214 (21.7)
Stray dogs									
No	65 (52.4)	101 (99.0)	107 (86.3)	119 (95.2)	108 (87.1)	108 (86.4)	125 (99.2)	134 (97.8)	867 (87.8)
Yes	59 (47.6)	1 (1.0)	17 (13.7)	6 (4.8)	16 (12.9)	17 (13.6)	1 (0.8)	3 (2.2)	120 (12.1)
Dogs barking at night									
No	77 (62.1)	102 (100.0)	107 (86.3)	100 (80.0)	95 (76.6)	109 (87.2)	119 (94.4)	128 (93.4)	837 (84.8)
Yes	47 (37.9)	–	17 (13.7)	25 (20.0)	29 (23.4)	16 (12.8)	7 (5.6)	9 (6.5)	150 (15.2)

end of the survey, 4416 pregnant women), demonstrated that <0.1% reported using recreational drugs during this pregnancy, 0.1% started smoking after entry into the study and 0.2% took up a high-risk occupation during pregnancy as defined using the same job list as during the survey.

Discussion

The women who participated in FGLS were selected to be at low risk of pregnancy complications, which included living in urban environments with a low risk of socio-economic constraints and environmental hazards related to adverse pregnancy outcomes. Specifically, the FGLS protocol required participants to be selected 'from populations with absence of known nonmicrobiological contamination such as pollution, domestic smoke, radiation or any other toxic substances….'

The MEA form was specifically developed to evaluate, at cluster level, the presence of major contaminants within the selected geographical areas. As individual women were not linked to their medical records, we do not aim to control for these exposures in future statistical analyses. For the most part, we confirmed that the women enrolled in FGLS had little exposure to domestic and occupational contaminants and hazards, and lived in what are recognised to be middle-class, urban areas in their respective countries.

Table 4. The occupational characteristics and hazards of 987 pregnant women by study site, FGLS, 2011–12

	Brazil *n* = 124 (%)	China *n* = 102 (%)	India *n* = 124 (%)	Italy *n* = 125 (%)	Kenya *n* = 124 (%)	Oman *n* = 125 (%)	UK *n* = 126 (%)	USA *n* = 137 (%)	Total *n* = 987 (%)
Employed during pregnancy									
No	31 (25.0)	41 (40.2)	106 (85.5)	29 (23.2)	21 (16.9)	62 (49.6)	12 (9.5)	25 (18.2)	327 (33.1)
Yes	93 (75.0)	61 (59.8)	18 (14.5)	96 (76.8)	103 (83.1)	63 (50.4)	114 (90.5)	112 (81.8)	660 (66.9)
Hours employed per week									
1–30 hours	29 (31.2)	2 (3.3)	3 (16.7)	25 (26.0)	12 (10.8)	7 (11.1)	28 (24.6)	36 (32.1)	142 (21.5)
31–40 hours	40 (43.5)	49 (80.3)	3 (16.7)	55 (57.3)	52 (51.0)	43 (68.3)	72 (63.2)	52 (46.4)	367 (55.6)
41+ hours	23 (25.0)	10 (16.4)	12 (66.7)	16 (16.7)	39 (38.2)	13 (20.6)	14 (12.3)	24 (21.4)	151 (22.9)
Employment place									
Inside home	8 (8.6)	61 (100.0)	4 (22.2)	5 (5.2)	3 (2.9)		9 (7.9)	15 (13.4)	105 (15.9)
Outside home	85 (91.4)		14 (77.8)	91 (94.8)	100 (97.1)	63 (100.0)	105 (92.1)	97 (86.6)	555 (84.1)
Work position									
Sitting	56 (60.2)	60 (98.4)	13 (72.2)	65 (67.7)	75 (72.8)	44 (69.8)	82 (71.9)	85 (75.9)	480 (72.7)
Standing	16 (17.2)	1 (1.6)	3 (16.7)	19 (19.8)	13 (12.6)	11 (17.5)	16 (14.0)	17 (15.2)	96 (14.5)
Walking	21 (22.6)	–	1 (5.6)	3 (3.1)	14 (13.6)	8 (12.7)	15 (13.2)	9 (8.0)	71 (10.8)
Other	–	–	1 (5.6)	9 (9.4)	1 (1.0)	–	1 (0.9)	1 (0.9)	13 (2.0)
Worked in a potentially hazardous business/industry									
No	70 (75.3)	59 (96.7)	10 (55.6)	74 (77.1)	87 (84.5)	51 (81.0)	81 (71.1)	84 (75.0)	516 (78.2)
Yes	23 (24.7)	2 (3.3)	8 (44.4)	22 (22.9)	16 (15.5)	12 (19.0)	33 (28.9)	28 (25.0)	144 (21.8)
Done potentially hazardous activities at work									
No	71 (76.3)	61	13 (72.2)	84 (87.5)	92 (89.3)	63 (100.0)	93 (81.6)	90 (80.4)	567 (85.9)
Yes	22 (23.7)	–	5 (27.8)	12 (12.5)	11 (10.7)	–	21 (18.4)	22 (19.6)	93 (14.1)
Very cold (less than 60°F/15°C)									
No	78 (83.9)	61 (100.0)	12 (66.7)	89 (92.7)	96 (93.2)	51 (81.0)	107 (93.9)	107 (95.5)	601 (91.1)
Yes	15 (16.1)	–	6 (33.4)	7 (7.3)	7 (6.8)	12 (19.0)	7 (6.2)	5 (4.5)	59 (9.0)
Very hot (greater than 80°F/27°C)									
No	68 (73.1)	61 (100.0)	16 (88.9)	77 (80.2)	89 (86.4)	57 (90.5)	95 (83.3)	107 (95.5)	570 (86.4)
Yes	25 (26.9)	–	2 (11.2)	19 (19.8)	14 (13.6)	6 (9.5)	19 (16.7)	5 (4.5)	90 (13.7)
Loud (can't hear neighbours speak)									
No	57 (61.3)	58 (95.1)	14 (77.8)	77 (80.2)	89 (86.4)	52 (82.5)	103 (90.4)	107 (95.5)	557 (84.4)
Yes	36 (38.7)	3 (4.9)	4 (22.3)	19 (19.8)	14 (13.6)	11 (17.5)	11 (9.6)	5 (4.5)	103 (15.6)
Dusty									
No	83 (89.2)	61 (100.0)	15 (83.3)	87 (90.6)	83 (80.6)	54 (85.7)	106 (93)	109 (97.3)	598 (90.6)
Yes	10 (10.8)	–	3 (16.7)	9 (9.3)	20 (19.4)	9 (14.3)	8 (7.1)	3 (2.7)	62 (9.4)
Poorly ventilated									
No	71 (76.3)	60 (98.4)	16 (88.9)	84 (87.5)	90 (87.4)	55 (87.3)	103 (90.4)	109 (97.3)	588 (89.1)
Yes	22 (23.7)	1 (1.6)	2 (11.2)	12 (12.5)	13 (12.6)	8 (12.7)	11 (9.6)	3 (2.7)	72 (10.9)
Symptoms from work									
No	67 (72.0)	59 (96.7)	11 (61.1)	72 (75.0)	98 (95.1)	29 (46.0)	95 (83.3)	110 (98.2)	541 (82.0)
Yes	26 (28.0)	2 (3.3)	7 (38.9)	24 (25.0)	5 (4.9)	34 (54.0)	19 (16.7)	2 (1.8)	119

This is remarkable despite the obvious cultural and geographical differences among study sites. This pattern correlates with the INTERGROWTH-21st selection protocol and the efforts made to identify geographical areas in developed and developing countries where women have low-risk pregnancies and are not socio-economically disadvantaged. Specifically, we aimed to select healthy low-risk women, but to avoid selecting those households or women that are at the very high end of the socio-economic scale, which would considerably reduce the external validity of the observed growth patterns.

Nevertheless, the MEA form did identify some potential environmental concerns. For example, we found that a significant proportion of women in some of the study sites reported living in houses with high residential density (more than one person per room[12]) that could lead to increased ingress of environmental exposures[11] and higher rates of infectious diseases.[13,14] We found that 14.1% of women reported peeling paint. It is likely that the resulting

Table 5. Industries employing the 660 women who worked during pregnancy by study site, FGLS, 2011–12

	Brazil *n* = 93 (%)	China *n* = 61 (%)	India *n* = 18 (%)	Italy *n* = 96 (%)	Kenya *n* = 103 (%)	Oman *n* = 63 (%)	UK *n* = 114 (%)	USA *n* = 112 (%)	Total *n* = 660 (%)
Janitor or house cleaning services	3 (11.1)	–	–	3 (13.6)	–	–	–	1 (3.6)	7 (4.5)
Hair salon	2 (7.4)	–	1 (12.5)	6 (27.3)	–	–	3 (7.9)	1 (3.6)	13 (8.4)
Nail salon	1 (3.7)	–	–	4 (18.2)	–	–	1 (2.6)	–	6 (3.9)
Construction	2 (7.4)	–	1 (12.5)	1 (4.5)	–	–	–	1 (3.6)	5 (3.2)
Healthcare or dentist surgery	8 (29.6)	2 (100.0)	2 (25.0)	3 (13.6)	14 (82.4)	12 (100.0)	18 (47.4)	13 (46.4)	72 (46.8)
Science laboratory	2 (7.4)	–	2 (25.0)	–	–	–	11 (28.9)	10 (62.5)	25 (17.6)
Farm/plant nursery, landscaping, ground keeping	4 (14.8)	–	–	1 (4.5)	2 (11.8)	–	–	1 (6.3)	8 (5.6)
Printing company	–	–	–	1 (4.5)	1 (5.9)	–	1 (2.6)	–	3 (1.9)
Hazardous waste	2 (7.4)	–	–	–	–	–	–	–	2 (1.3)
Electronics manufacturing	–	–	–	1 (4.5)	–	–	1 (2.6)	–	2 (1.3)
Plastic products or manufacturing	–	–	–	–	–	–	2 (5.3)	–	2 (1.3)
Other manufacturing	3 (11.1)	–	2 (25.0)	2 (9.1)	–	–	1 (2.6)	1 (3.6)	9 (5.8)

Table 6. Potential hazardous activities at work reported by 167 pregnant women by study site, FGLS, 2011–12

	Brazil *n* = 34 (%)	China *n* = 0 (%)	India *n* = 5 (%)	Italy *n* = 17 (%)	Kenya *n* = 23 (%)	Oman *n* = 0 (%)	UK *n* = 39 (%)	USA *n* = 49 (%)	Total *n* = 167 (%)
Make or spray (pesticides, fungicides)	2 (5.9)	–	–	1 (5.9)	1 (4.3)	–	–	3 (6.1)	7 (4.2)
Apply varnish, finish or seals	1 (2.9)	–	–	1 (5.9)	–	–	1 (2.6)	–	3 (1.8)
Mix or apply paints or lacquers	2 (5.9)	–	–	1 (5.9)	–	–	2 (5.1)	–	5 (3.0)
Use solvents or degreasers	–	–	–	4 (23.5)	–	–	2 (5.1)	6 (12.2)	12 (7.2)
Apply glues or adhesives	2 (5.9)	–	–	2 (11.8)	–	–	3 (7.7)	1 (2.0)	8 (4.8)
Degrease tools, machines or electronics	1 (2.9)	–	1 (20.0)	–	–	–	–	–	2 (1.2)
Weld	1 (2.9)	–	–	–	–	–	–	–	1 (0.6)
Use X-ray or radioactive substances	1 (2.9)	–	–	–	4 (17.4)	–	4 (10.3)	5 (10.2)	14 (8.4)
Use janitorial/cleaning chemicals	11 (32.4)	–	–	2 (11.8)	–	–	6 (15.4)	5 (10.2)	24 (14.4)
Use dyes (for hair or textiles)	2 (5.9)	–	1 (20.0)	3 (17.6)	–	–	2 (5.1)	4 (8.2)	12 (7.2)
Apply artificial nails	–	–	–	2 (11.8)	–	–	1 (2.6)	2 (4.1)	5 (3.0)
Handle or make pharmacy drugs	3 (8.8)	–	1 (20.0)	–	7 (30.4)	–	7 (17.9)	2 (4.1)	20 (12.0)
Work with laboratory chemicals	4 (11.8)	–	1 (20.0)	–	–	–	6 (15.4)	7 (14.3)	18 (10.8)
Work with anaesthetic gases or sterilisers	–	–	–	–	6 (26.1)	–	1 (2.6)	3 (6.1)	10 (6.0)
Use strong acids or bases	2 (5.9)	–	–	–	–	–	3 (7.7)	8 (16.3)	13 (7.8)
Use lead or other metals	–	–	1 (20.0)	1 (5.9)	2 (8.7)	–	–	–	4 (2.4)
Use other chemicals	2 (5.9)	–	–	–	3 (13.0)	–	1 (2.6)	3 (6.1)	9 (5.4)

paint chips contain lead if the housing stock is old, and this could be hazardous to the young child.[15] We also found that a substantial proportion of women reported cockroach infestations. This could also lead to increased pesticide usage. Methods of integrative pest management could be taught to pregnant women to reduce exposure to such chemicals, which have the potential to have an impact on fetal brain development.[16,17]

Many women boiled water before use (such as women in China, India and Kenya) or relied on bottled water

(close to half of the women in Brazil, Italy and Oman). Given that most bottled water is sold in plastic bottles; this could result in maternal and fetal exposure to plasticisers such as bisphenol A and phthalates,[18] known endocrine-disrupting chemicals.[19] Lastly, many women reported living in neighbourhoods considered to be noisy and/or perceived to be unsafe, particularly women in Brazil, Italy, Kenya and Oman.

These findings are particularly noteworthy given that the women from the eight FGLS populations are from primarily low-risk middle- to upper-class populations; many others are likely to be worse off. Hence, despite the major progress that has been achieved in recent decades, considerable efforts are still needed to reduce environmental risks, which may have an impact on the health of fetuses and children.

The process we followed to construct the MEA form has limitations. We did not validate the report of exposures with home visits, or biological or environmental measurements. However, responses to the questions about employment in high-risk occupations during pregnancy and smoking included in the survey matched the antenatal care data, obtained during each clinic visit, from the complete FGLS study population. These data confirmed, for example, that participants live in smoke-free environments and, during their pregnancy, only a very small number started work that carried potential risk. Similarly, the general description of the housing stock is consistent with the study's targeted socio-economic level, which is described elsewhere.[9]

Another limitation is that we did not include a random sample of all women participating in FGLS. Instead, we applied the MEA form to all women enrolled in FGLS attending antenatal care during a fixed time within the complete study period. This sampling method may have introduced selection and temporal bias. It is possible that selection bias could have occurred with an overrepresentation of women willing to provide a detailed description of their life. However, we do not have any reason to believe that the environmental conditions of the communities and the risk profiles of the women changed over such a short period of time. The sample was also not large enough to stratify by gestational age. Consequently, the findings reflect average exposures of the FGLS participants, as required by the protocol, and were not intended to identify individuals, or subpopulations (in which there were only a few women) or patterns for each country as a whole.

Some questions in the form, such as neighbourhood descriptions, are prone to response and social desirability bias and should be complemented with additional instruments. In addition, cultural differences may play a role as to whether women consider certain factors to be desirable or report concerns and this may have led to discrepancies across countries.

One other limitation of the MEA form is that, although it is quite comprehensive, it does not address all aspects of the environment, nor does it quantify exposure levels. Although measurements in environmental and biological samples have been used to evaluate exposures to environmental contaminants in epidemiological studies of pregnant women,[20–22] this option was considered impractical in FGLS given (1) that it was not the aim of this component of FGLS, (2) the wide range of potential contaminants in urban areas across eight countries and (3) the cost of measuring these contaminants.

Nevertheless, the MEA instrument could be used to identify potentially confounding exposure variables in perinatal epidemiological studies, and as a screening tool to generate hypotheses and refine biological or environmental sampling protocols. In addition, it could be used as a broad and brief assessment of environmental concerns in a general population or in samples of pregnant women suspected to be at risk, which could help inform policy and urban planning and guide health educators in developing programmes.

In summary, in this study of close to 1000 pregnant women, we have tested a new data collection instrument and shown its potential utility as a tool to assess environmental exposures during pregnancy internationally. Given its brevity yet comprehensiveness, the MEA form should be considered for use in screening populations of pregnant women for environmental exposures across the globe.

Disclosure of interests

None.

Contribution to authorship

B Eskenazi, A Bradman, D Finkton and J Villar wrote the manuscript and all the authors read and approved the final version.

Details of ethics approval

The INTERGROWTH-21st Project was approved by the Oxfordshire Research Ethics Committee 'C' (reference:08/H0606/139) and the research ethics committees of the individual participating institutions and corresponding health authorities where the project was implemented.

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References

1 Blencowe H, Cousens S, Oestergaard MZ, Chou D, Moller AB, Narwal R, et al. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet* 2012;379:2162–72.

2 Kharrazi M, DeLorenze GN, Kaufman FL, Eskenazi B, Bernert JT Jr, Graham S, et al. Environmental tobacco smoke and pregnancy outcome. *Epidemiology* 2004;15:660–70.

3 Rahman A, Persson LA, Nermell B, El Arifeen S, Ekstrom EC, Smith AH, et al. Arsenic exposure and risk of spontaneous abortion, stillbirth, and infant mortality. *Epidemiology* 2010;21:797–804.

4 World Health Organization ECfEaH. *Effects of Air Pollution on Children's Health and Development—A Review of the Evidence*. Geneva: WHO, 2005.

5 Eskenazi B, Harley K, Bradman A, Weltzien E, Jewell NP, Barr DB, et al. Association of in utero organophosphate pesticide exposure and fetal growth and length of gestation in an agricultural population. *Environ Health Perspect* 2004;112:1116–24.

6 Apelberg BJ, Witter FR, Herbstman JB, Calafat AM, Halden RU, Needham LL, et al. Cord serum concentrations of perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA) in relation to weight and size at birth. *Environ Health Perspect* 2007;115:1670–6.

7 Figa-Talamanca I. Occupational risk factors and reproductive health of women. *Occup Med (Oxf, Engl)* 2006;56:521–31.

8 Barr JR, Driskell WJ, Hill RH Jr, Ashley DL, Needham LL, Head SL, et al. Strategies for biological monitoring of exposure for contemporary-use pesticides. *Toxicol Ind Health* 1999;15:168–79.

9 Villar J, Altman D, Purwar M, Noble J, Knight H, Ruyan P, et al. for the International Fetal and Newborn Growth Consortium for the 21st Century (INTERGROWTH-21st). The objectives, design and implementation of the multicentre, population-based, INTERGROWTH-21st Project. *BJOG* 2013;120 (Suppl. 2):9–25.

10 Eskenazi B, Bradman A, Gladstone EA, Jaramillo S, Birch K, Holland NT. CHAMACOS, a longitudinal birth cohort study: lessons from the fields. *J Child Health* 2003;1:3–27.

11 Bradman A, Chevrier J, Tager I, Lipsett M, Sedgwick J, Macher J, et al. Association of housing disrepair indicators with cockroach and rodent infestations in a cohort of pregnant Latina women and their children. *Environ Health Perspect* 2005;113:1795–801.

12 Blake KS, Kellerson RL, Simic A. *Measuring Overcrowding in Housing*. Bethesda, MD: US Department of Housing and Urban Development, 2007. [www.huduser.org/Publications/pdf/Measuring_Overcrowding_in_Hsg.pdf]. Accessed 12 April 2013.

13 Stein L. A study of respiratory tuberculosis in relation to housing conditions in Edinburgh. I. The pre-war period. *Br J Soc Med* 1950;4:143–69.

14 Fonseca W, Kirkwood BR, Victora CG, Fuchs SR, Flores JA, Misago C. Risk factors for childhood pneumonia among the urban poor in Fortaleza, Brazil: a case—control study. *Bull World Health Organ* 1996;74:199–208.

15 Needleman HL, Gunnoe C, Leviton A, Reed R, Peresie H, Maher C, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels [published erratum appears in *N Engl J Med* 1994;331:616]. *N Engl J Med* 1979;300:689–95.

16 Bouchard MF, Chevrier J, Harley KG, Kogut K, Vedar M, Calderon N, et al. Prenatal exposure to organophosphate pesticides and IQ in 7-year-old children. *Environ Health Perspect* 2011;119:1189–95.

17 US Environmental Protection Agency. *Integrated Pest Management (IPM) Principles*. Washington DC: USEPA, 2012.

18 Carwile JL, Luu HT, Bassett LS, Driscoll DA, Yuan C, Chang JY, et al. Polycarbonate bottle use and urinary bisphenol A concentrations. *Environ Health Perspect* 2009;117:1368–72.

19 Schug TT, Janesick A, Blumberg B, Heindel JJ. Endocrine disrupting chemicals and disease susceptibility. *J Steroid Biochem Mol Biol* 2011;127:204–15.

20 Needham LL, Ozkaynak H, Whyatt RM, Barr DB, Wang RY, Naeher L, et al. Exposure assessment in the National Children's Study: introduction. *Environ Health Perspect* 2005;113:1076–82.

21 Bradman A, Whyatt RM. Characterizing exposures to nonpersistent pesticides during pregnancy and early childhood in the National Children's Study: a review of monitoring and measurement methodologies. *Environ Health Perspect* 2005;113:1092–9.

22 Fenske RA, Bradman A, Whyatt RM, Wolff MS, Barr DB. Lessons learned for the assessment of children's pesticide exposure: critical sampling and analytical issues for future studies. *Environ Health Perspect* 2005;113:1455–62.