Original Research

Anaemia control: Lessons from the flour fortification programme

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SUMMARY

Objectives: Anaemia is an important public health problem in Iran; therefore, a programme of flour fortification with iron was launched in two pilot provinces. The present study was conducted in January 2009 to evaluate the effectiveness and process of this programme.

Study design: A 'before-and-after study' was conducted to evaluate the effectiveness of the flour fortification programme, and the process of the programme was evaluated using a cross-sectional study.

Methods: To evaluate the effectiveness of the programme, blood haemoglobin and ferritin levels were measured in sample populations from Bushehr and Golestan provinces. The target population was women aged 15–49 years. Iron content was measured in samples of flour and bread to evaluate the flour fortification process in these two national pilot provinces.

Results: The total study population was 600 women from Bushehr province and 652 women from Golestan province. Similar trends were found in the indicators of anaemia/iron deficiency among the women studied in both provinces. The flour fortification programme only appears to have had a beneficial effect on ferritin levels (iron deficiency) in the two provinces. The prevalence of iron-deficiency anaemia before and after the intervention did not differ significantly in either province. Interestingly, the prevalence of anaemia (low haemoglobin) was significantly higher after the intervention in women from both provinces. The coverage of fortified flour and bread was 90% and 98.7% in Bushehr province, and 94.1% and 95% in Golestan province, respectively.

Conclusions: In areas where anaemia is not mainly due to iron deficiency, an iron fortification programme might decrease the prevalence of iron deficiency without affecting the prevalence of anaemia.

Introduction

Anaemia is a worldwide public health problem. The World Health Organization (WHO) estimates that anaemia affects 1.62 billion people worldwide, corresponding to 24.8% of the human population. The highest worldwide prevalence of anaemia is seen in Africa, but the largest number of affected individuals is found in South-East Asia, where 315 million individuals are affected.1

More than 50% of worldwide anaemia is due to nutritional iron deficiency,2 which is an important public health problem in both developing and developed countries.1 According to WHO mortality data, approximately 0.8 million deaths (1.5% of total worldwide deaths) can be attributed to iron deficiency each year.3

Maternal anaemia is associated with intra-uterine growth retardation, low birth weight, increased perinatal mortality, and increased maternal morbidity and mortality. Iron-deficiency anaemia may cause cognitive deficits in young children and can affect later motor development and school performance.4 In developing countries, severe anaemia is the main causal factor in up to 20% of maternal deaths.2,5,6 Approximately one-fifth of cases of perinatal mortality and one-tenth of cases of maternal mortality in developing countries are attributable to iron deficiency.7 Iron-deficiency anaemia is a serious public health problem in all of the countries comprising the Eastern Mediterranean Region of WHO, as well as the Middle East and North African Regions of the United Nations Children’s Fund (UNICEF).8

There are four basic strategies for addressing micronutrient deficiencies: food fortification, supplementation, dietary diversification, and other public health measures (e.g. promoting breast feeding and controlling parasitic infestations). The present study will focus on food fortification, which is an important strategy for
improving the nutritional situation of populations. Mandatory fortification of flour with iron has been implemented in developed countries for many years,\(^9\)-\(^13\) and appears to be an effective approach for combating iron deficiency.\(^14\)-\(^15\) Food fortification in Europe has been shown to contribute positively to the micronutrient status of adults\(^16\) and children.\(^17\)

Common food vehicles used around the world for iron fortification include processed cereals (e.g. wheat and corn), salt, sugar, condiments and other processed foods.\(^3\)-\(^8\) Bread consumption is high in most countries of the Eastern Mediterranean Region of WHO. As such, flour fortification offers an opportunity to deliver adequate levels of iron; this strategy has been implemented in a number of countries in the region.\(^9\)

In Iran, anaemia and iron deficiency are important public health problems. A national study conducted by the Ministry of Health and Medical Education (MOHME) and UNICEF in 1999 showed that 33.4% of Iranian women were anaemic according to haemoglobin levels, 34.5% were iron deficient according to serum ferritin levels, and 16.6% suffered from iron-deficiency anaemia.\(^18\)-\(^19\) Given that dietary data indicated that cereals provided 63% of the total energy intake in Iran, the estimated national per capita consumption of wheat in 1993 was 178 kg/year, and consumption of bread ranged from 230 to 505 g/pers/day.\(^2\) Iron fortification of wheat flour was considered to be an ideal strategy for addressing iron deficiency in Iran.

On 31 May 2001, MOHME launched a programme to fortify flour with iron and folic acid in Bushehr province, which was selected for the pilot programme because of the high prevalence of iron deficiency and anaemia among women of childbearing age.\(^20\) The iron-fortified flour premix was produced inside Iran and included 30 ppm ferrous sulphate and 1.5 ppm folic acid.

As is true of any programme aimed at improving health, programmes involving fortification of staple foods such as wheat flour must be subjected to systematic monitoring and evaluation to demonstrate whether or not fortification has been effective.\(^21\)-\(^22\) The authors selected several indicators for evaluating the process and effectiveness of the flour fortification programme in Iran. These were based on the indicators suggested by the Centers for Disease Control and Prevention (CDC), Pan American Health Organization/WHO and United States Agency for International Development for monitoring and evaluating food fortification programmes.\(^23\) The indicator ‘fortified food availability’ or ‘programme coverage’ was selected for process evaluation, and the indicator ‘changes in biochemical indicators of deficiency’ was selected for effectiveness evaluation.

The first evaluation in Bushehr province was conducted in 2004. The first study (2004) was a field trial to evaluate the effectiveness of the programme.\(^24\) The intervention province (Bushehr) was compared with a control province (Fars) for anaemia and iron-deficiency indicators. The target population was women aged 15–49 years and men aged 40–60 years. The findings of the first evaluation suggested that the iron fortification programme in Iran had a beneficial effect, but only on ferritin indicators (iron deficiency) among women. Importantly, the iron fortification programme did not have adverse effects on men, namely increased haemoglobin and ferritin levels. This type of field trial study design could not be used for other evaluations, as the flour fortification programme had been expanded into other provinces (including Fars province) by the time the later studies were conducted. Therefore, the next evaluations were designed as before-and-after studies. The second evaluation in Bushehr province was conducted in 2007. The findings of the second evaluation showed that women and men in Bushehr province had a lower prevalence of low ferritin levels compared with the baseline (pre-intervention) sample. There was no significant difference in the prevalence of iron-deficiency anaemia between the study and baseline samples, but the prevalence of anaemia (low haemoglobin) was significantly higher in the 2007 sample compared with the baseline (2001) sample among both women and men. Based on these findings in Bushehr province, it was recommended that another study should be conducted to confirm the results of the second evaluation. As the iron fortification programme in Iran does not appear to have adverse effects on men, MOHME decided to exclude this group from the next evaluation.

Meanwhile, the results of the National Integrated Micronutrient Survey conducted by the Nutrition Department of MOHME showed a high prevalence of anaemia, according to haemoglobin levels, in Golestan province. As a result, MOHME launched a programme to fortify flour with iron and folic acid in Golestan province, which was selected for the second pilot programme. Flour fortification with iron and folic acid was conducted in Golestan province in February 2007, and baseline data were gathered before the flour fortification in May 2007.

In 2008, the World Bank suggested that parallel evaluations should be conducted in Bushehr and Golestan provinces. Therefore, the present study was conducted in January 2009 to evaluate the effectiveness and process of flour fortification with iron and folic acid in these two Iranian provinces. The present study constitutes the third evaluation in Bushehr province and the first evaluation in Golestan province.

**Methods**

**Study design**

This study included an effectiveness evaluation and a process evaluation. The study population was selected from Bushehr and Golestan provinces. The study was conducted from January to April 2009.

The effectiveness of the programme was evaluated using a before-and-after study. The target population was women aged 15–49 years. Women of reproductive age were selected because maternal anaemia results in increased perinatal and maternal morbidity and mortality. The process of the programme was evaluated using a cross-sectional study that measured iron content in samples of flour and bread.

**Sample size and sampling**

The sample size and sampling methods were similar in all evaluations of the flour fortification programme in each province.

**Effectiveness evaluation**

The sample size was 600 women in each province. To detect a reduction of 8% in overall anaemia in women of reproductive age with 80% power, a two-sided type I error of 5% and a design effect of 2, it was calculated that approximately 600 women would be required in each province. A cluster sampling method was used to sample women of reproductive age. In Bushehr province, each cluster comprised four women, and 150 clusters were selected from among the women. In Golestan province, each cluster comprised 10 women, and 60 clusters were selected from among the women.

**Process evaluation**

In Bushehr province, the iron content was measured in 150 bread samples (one from the home of a woman in each cluster) and in flour samples from 50 bakeries (10% of the total number of bakeries, selected by systematic sampling). In Golestan province, the iron content was measured in 120 bread samples (two from
each cluster) and in flour samples from 120 bakeries (7% of the total number of bakeries, selected by systematic sampling).

Data collection

Effectiveness evaluation

Blood samples were taken and tested for haemoglobin and ferritin levels. Haemoglobin was tested in each province using one selected laboratory. The complete blood count was performed using a KX-21N (Sysmex) cell counter, and the haemoglobin component was measured. A control solution (Labex) was used as a blood reference, and device and quality control checks were performed before and after daily analysis of the collected blood samples. For ferritin testing, all blood samples were transported to Tehran City and tested in the Pardtan Elin Laboratory. Ferritin levels were measured using an Enzyme Immunoassay (EIA) kit, and the results were validated by laboratory controls. The same methods for measuring complete blood count and serum ferritin had been used in all previous evaluations of the flour fortification programme in Iran. Finally, a questionnaire was used to obtain data regarding potential confounders. All subjects signed informed consent forms and agreed to participate in this study.

Process evaluation

The dependent variable was the iron concentration in the bread and flour samples, which was assayed using a spectrophotometric method (AACC 40–41B). A ‘low’ iron level was defined as 25–39.9 ppm, a ‘good’ iron level was 40–65.9 ppm, an ‘acceptable’ iron level was 66–79.9 ppm, and a ‘high’ iron level was 80 ppm or above. These ranges were taken from the guidelines of the iron assay method.

Statistical analysis

The dependent variables were low haemoglobin level (anaemia), low serum ferritin level (iron deficiency), iron-deficiency anaemia, mean haemoglobin level and mean ferritin level. The haemoglobin thresholds were 12 g/dl in non-pregnant women and 11 g/dl in pregnant women; these values were based on the WHO, UNICEF and UNU guide for programme managers.25 The ferritin threshold was defined as 10 ng/ml in all women, according to the standard of the Enzyme Immunoassay (EIA) kit. Iron-deficiency anaemia was defined as having both low haemoglobin and low ferritin. As independent variables, data were collected for the characteristics considered to be potential confounding variables. However, it should be noted that some confounding variables were not collected at baseline in Bushehr province.

Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. Characteristics were analysed with χ2-test for categorical variables, and t-test for continuous variables. All indicators of anaemia/iron deficiency were adjusted for characteristics that were found to be significant (confounding variables) in the logistic regression model. P-values <0.05 were considered to be statistically significant.

Results

Effectiveness evaluation

Bushehr province

The total study population from Bushehr province was 600 women in 2009 (after intervention) and 593 women in 2001 (baseline). The characteristics of the women studied before and after the intervention are shown in Table 1. All indicators of anaemia/iron deficiency were adjusted for characteristics that were found to be significant (confounding variables) in the logistic regression model. In the present evaluation, there were no significant pre-/post-intervention differences in mean age (P = 0.8), use of iron supplementation (P = 0.2), positive blood donor history (P = 0.4), positive surgery history (P = 0.2), menstruation (P = 0.3), menopause (P = 1), marriage status (P = 0.4), pregnancy (P = 0.4) and mean months of gestation (P = 0.7). In contrast, there were significant pre-/post-intervention differences in urban location (P = 0.000), district distribution (P = 0.000) and education (% of illiterate women) (P = 0.000).

The indicator results for anaemia/iron deficiency at baseline (2001) and in the present evaluation (2009) are shown in Table 2. In Bushehr province, the prevalence of anaemia (low haemoglobin) increased significantly from 12.1% in 2001 to 20.8% in 2009 (P = 0.001), while the prevalence of iron deficiency (low ferritin) decreased significantly from 22.2% in 2001 to 15.7% in 2009 (P = 0.002). Consistent with these findings, the mean haemoglobin levels were significantly different between 2001 and 2009 [13.6 (SD 1.6) g/dl vs 12.9 (SD 1.4) g/dl; P = 0.000], as were the mean ferritin levels [32.8 (SD 48.4) ng/ml vs 41.9 (SD 44.3) ng/ml; P = 0.001]. There was no significant difference in the prevalence of iron-deficiency anaemia in this province between 2001 and 2009 (P = 0.4).

In the present evaluation (2009), according to the previous evaluation (2007), the prevalence of anaemia was increased relative to baseline (2001). To determine whether this was due to the presence of confounding variables, potential confounders were examined in the present evaluation. It was possible to define some differences in the characteristics of women before and after intervention.

Table 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline 2001 [% (n)]</th>
<th>Post intervention 2009 [% (n)]</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age ± SD (year)</td>
<td>30.9 ± 8.6 (593)</td>
<td>30.8 ± 8.5 (600)</td>
<td>0.8</td>
</tr>
<tr>
<td>Urban location</td>
<td># (593)</td>
<td># (600)</td>
<td>0.000</td>
</tr>
<tr>
<td>District distributionb</td>
<td># (593)</td>
<td># (600)</td>
<td>0.000</td>
</tr>
<tr>
<td>Education (illiterate women)</td>
<td>22.9 (593)</td>
<td>6.2 (599)</td>
<td>0.000</td>
</tr>
<tr>
<td>Use of iron supplementation</td>
<td>7.9 (593)</td>
<td>10.0 (600)</td>
<td>0.2</td>
</tr>
<tr>
<td>Positive blood donor history</td>
<td>0.7 (593)</td>
<td>1.3 (600)</td>
<td>0.4</td>
</tr>
<tr>
<td>Positive surgery history</td>
<td>4.6 (593)</td>
<td>3.6 (600)</td>
<td>0.2</td>
</tr>
<tr>
<td>Menstruation</td>
<td>15.3 (593)</td>
<td>17.7 (600)</td>
<td>0.3</td>
</tr>
<tr>
<td>Menopause</td>
<td>3 (593)</td>
<td>3 (599)</td>
<td>1</td>
</tr>
<tr>
<td>Married women</td>
<td>82.5 (593)</td>
<td>77.7 (600)</td>
<td>0.4</td>
</tr>
<tr>
<td>Pregnant women</td>
<td>6.1 (489)</td>
<td>4.7 (465)</td>
<td>0.4</td>
</tr>
<tr>
<td>Mean months of gestation ± SD</td>
<td>5.5 ± 2.4 (30)</td>
<td>5.3 ± 2.2 (22)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

SD, standard deviation.

* P < 0.05 considered to be statistically significant.

b There are nine districts in Bushehr province; the distribution of the study population by district is not presented in this table (for brevity).

Table 2

<p>| Anaemia/iron-deficiency indicators at baseline (2001) and post intervention (2009), Bushehr province, Iran. |
|---------------------------------------------------------------|---------------------------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline (2001) [% (n)]</th>
<th>Post intervention (2009) [% (n)]</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low haemoglobin (%)</td>
<td>12.1 (585)</td>
<td>20.8 (600)</td>
<td>0.001</td>
</tr>
<tr>
<td>Low ferritin (%)</td>
<td>22.2 (576)</td>
<td>15.7 (600)</td>
<td>0.002</td>
</tr>
<tr>
<td>Mean haemoglobin ± SD (g/dl)</td>
<td>13.6 ± 1.6 (585)</td>
<td>12.9 ± 1.4 (600)</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean ferritin ± SD (ng/ml)</td>
<td>32.8 ± 48.4 (576)</td>
<td>41.9 ± 44.3 (600)</td>
<td>0.001</td>
</tr>
<tr>
<td>Iron-deficiency anaemia (%)</td>
<td>5.3 (570)</td>
<td>7 (600)</td>
<td>0.4</td>
</tr>
</tbody>
</table>

SD, standard deviation.

* P < 0.05 considered to be statistically significant. P-values were adjusted for characteristics found to be significant in the logistic regression. These included ‘urban’, ‘district’ and ‘education’.

* n-values are shown in parentheses.
determining factors for anaemia (low haemoglobin); these included a history of chronic disease, medication, pattern of bread consumption and trend of household salary changes. All of these variables were self-reported. As baseline data were not available for all of these factors, a cross-sectional statistical analysis was performed using the 2009 data. In 2009, the prevalence of low haemoglobin levels did not differ significantly between healthy and sick women (P = 0.16); women who were and those who were not taking medication (P = 0.15); women whose bread consumption had increased, decreased or remained the same since the first evaluation (P = 0.3); and women whose household salaries had increased, decreased or remained the same since the first evaluation (P = 0.8).

Golestan province

The total study population from Golestan province was 652 women in 2009 (post intervention) and 579 women in 2007 (baseline). The total number of women studied in 2009 was more than the projected sample size because some blood samples were lost through clotting, so additional subjects were added and sampled. The characteristics of the women studied in 2007 (pre intervention) and 2009 (post intervention) are shown in Table 3. All indicators of anaemia/iron deficiency were adjusted for characteristics that were found to be significant (confounding variables) in the logistic regression model. In the present evaluation, there were no significant pre-/postintervention differences in mean age (P = 0.1), urban location (P = 0.6), district distribution (P = 0.9), family numbers (P = 0.08), anaemia history (P = 0.2), use of iron supplementation (P = 0.2), positive donor history (P = 0.7), positive surgery history (P = 0.2), smoking (P = 0.4), passive smoking (P = 0.3), chronic diseases (P = 0.1), menstruation (P = 0.9), marriage status (P = 0.2), pregnancy (P = 1), mean months of gestation (P = 0.4), mean number of deliveries (P = 0.96) and breast feeding (P = 0.9). In contrast, there were significant pre-/post intervention differences in education (P = 0.001) and menopause (P = 0.000).

The indicator results for anaemia/iron deficiency at baseline (2007) and in the present evaluation (2009) are shown in Table 4. In Golestan province, the prevalence of anaemia (low haemoglobin) increased significantly from 19.3% in 2007 to 25.6% in 2009 (P = 0.01), while the prevalence of low ferritin (iron deficiency) decreased significantly from 26.7% in 2007 to 14.6% in 2009 (P = 0.000). Consistent with these findings, the mean haemoglobin levels were significantly different between 2007 and 2009 [12.9 (SD 1.3) g/dl vs 12.5 (SD 1.1) g/dl; P = 0.000], as were the mean ferritin levels [31.5 (SD 42.9) ng/ml vs 47.7 (SD 46.3) ng/ml; P = 0.000]. There was no significant pre-/post intervention difference in the prevalence of iron-deficiency anaemia in Golestan province (P = 0.2).

Process evaluation

Bushehr province

For the 2009 process evaluation, the iron content after fortification was measured in flour samples from all (n = 3) factories in Bushehr province. After iron fortification, the iron levels in flour were 50, 55 and 52 ppm in samples from the Alzahra, Borazjan and Khalji flour factories, respectively. These iron levels are defined as ‘good’. Next, the iron content of flour sampled (200 g) from 50 bakeries in Bushehr province was measured. The mean iron level in the flour samples was 45.1 (SD 15.7) ppm. This iron level is defined as ‘good’. The percentage of flour samples with no evidence of iron fortification was 10%. Therefore, the coverage of fortified flour was 90% in 2009.

One bread sample (200 g) was collected from every cluster. Therefore, 150 bread samples from Bushehr province were analysed in 2009. The mean iron level in bread was 49.8 (SD 11.9) ppm. This iron level is defined as ‘good’. Two bread samples (1.3%) showed no evidence of iron fortification. Therefore, the coverage of fortified bread was 98.7% in 2009.

Golestan province

In 2009, the iron content in flour samples obtained from all (n = 26) factories in Golestan province was analysed. After iron fortification, the iron levels in flour samples from five of these factories were lower than 40 ppm. Next, the iron content of flour sampled (200 g) from 119 bakeries in Golestan province was measured. The mean iron level in the flour samples was 48.9 (SD 18) ppm. This iron level is defined as ‘good’. In 2009, flour samples from seven bakeries (5.9%) showed no evidence of iron fortification. Therefore, the coverage of fortified flour was 94.1%.

One bread sample (200 g) was collected from every cluster. Therefore, 120 bread samples from Golestan province were analysed in 2009. The mean iron level in the bread samples was 51.4 (SD 24.5) ppm. This iron level is defined as ‘good’. Six bread samples

### Table 3

Characteristics of the studied women at baseline (2007) and post intervention (2009), Golestan province, Iran.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline (2007) [% (n)]</th>
<th>Post intervention (2009) [% (n)]</th>
<th>P-value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age ± SD (year)</td>
<td>31.4 ± 9.1 (579)</td>
<td>32.2 ± 8.5 (649)</td>
<td>0.1</td>
</tr>
<tr>
<td>Urban location</td>
<td>50.4 (579)</td>
<td>48.9 (652)</td>
<td>0.6</td>
</tr>
<tr>
<td>District distribution^b</td>
<td># (579)</td>
<td># (652)</td>
<td>0.9</td>
</tr>
<tr>
<td>Family numbers (less than 5)</td>
<td>48.2 (579)</td>
<td>52.7 (651)</td>
<td>0.08</td>
</tr>
<tr>
<td>Education (% of illiterate women)</td>
<td>10.1 (577)</td>
<td>16.7 (652)</td>
<td>0.001</td>
</tr>
<tr>
<td>Anaemia history</td>
<td>25.6 (579)</td>
<td>28.7 (651)</td>
<td>0.2</td>
</tr>
<tr>
<td>Use of iron supplementation</td>
<td>12.1 (579)</td>
<td>13.7 (651)</td>
<td>0.2</td>
</tr>
<tr>
<td>Positive blood donor history</td>
<td>0.3 (579)</td>
<td>0.6 (652)</td>
<td>0.7</td>
</tr>
<tr>
<td>Positive surgery history</td>
<td>2.1 (579)</td>
<td>1.1 (652)</td>
<td>0.2</td>
</tr>
<tr>
<td>Smoking</td>
<td>1.2 (579)</td>
<td>0.6 (652)</td>
<td>0.4</td>
</tr>
<tr>
<td>Passive smoking</td>
<td>25.7 (579)</td>
<td>22.4 (652)</td>
<td>0.3</td>
</tr>
<tr>
<td>Chronic diseases</td>
<td>21.7 (579)</td>
<td>17.5 (652)</td>
<td>0.1</td>
</tr>
<tr>
<td>Menstruation</td>
<td>18.1 (579)</td>
<td>17.9 (652)</td>
<td>0.9</td>
</tr>
<tr>
<td>Menopause</td>
<td>5.5 (579)</td>
<td>1.5 (652)</td>
<td>0.005</td>
</tr>
<tr>
<td>Married women</td>
<td>82.7 (579)</td>
<td>85.7 (652)</td>
<td>0.2</td>
</tr>
<tr>
<td>Pregnant women (%)</td>
<td>3.8 (479)</td>
<td>3.9 (559)</td>
<td>1</td>
</tr>
<tr>
<td>Mean months of gestation ± SD</td>
<td>5.7 ± 2.2 (17)</td>
<td>5 ± 2.4 (22)</td>
<td>0.4</td>
</tr>
<tr>
<td>Mean no. of deliveries ± SD</td>
<td>2.6 ± 1.9 (479)</td>
<td>2.6 ± 2.2 (559)</td>
<td>0.96</td>
</tr>
<tr>
<td>Breast feeding</td>
<td>17.5 (479)</td>
<td>17 (559)</td>
<td>0.9</td>
</tr>
</tbody>
</table>

SD, standard deviation.

** P < 0.05 considered to be statistically significant.

^b n-values are shown in parentheses.

### Table 4

Anaemia/iron-deficiency indicators at baseline (2007) and post intervention (2009), Golestan province, Iran.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Baseline (2007) [% (n)]</th>
<th>Post intervention (2009) [% (n)]</th>
<th>P-value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low haemoglobin (%)</td>
<td>19.3 (575)</td>
<td>25.6 (620)</td>
<td>0.01</td>
</tr>
<tr>
<td>Low ferritin (%)</td>
<td>26.7 (572)</td>
<td>14.6 (604)</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean haemoglobin ± SD (g/dl)</td>
<td>12.9 ± 3.3 (575)</td>
<td>12.5 ± 1.1 (620)</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean ferritin ± SD (ng/ml)</td>
<td>31.5 ± 42.9 (572)</td>
<td>47.7 ± 46.3 (604)</td>
<td>0.000</td>
</tr>
<tr>
<td>Iron-deficiency anaemia (%)</td>
<td>10.8 (572)</td>
<td>8.6 (572)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

SD, standard deviation.

** P < 0.05 considered to be statistically significant. P-values were adjusted for characteristics found to be significant in the logistic regression. These included ‘education’ and ‘menopause’.
(5%) in 2009 showed no evidence of iron fortification. Therefore, the coverage of fortified bread was 95%.

Discussion

During the latter half of the 20th Century, food fortification has played an important role in reducing iron deficiency in countries such as Canada, the USA, the UK and parts of Europe.26 Food fortification is believed to have significant potential for improving iron status in countries such as Venezuela, Vietnam, China, Mexico and the Philippines.72,28

The decline in iron deficiency in industrialized countries should not be solely attributed to food fortification; other factors have contributed, such as economic development and the implementation of specific policies for improving iron intake and reducing iron loss. However, the prevalence of iron deficiency in these countries remains high in selected subgroups, such as among women of reproductive age, who often develop iron deficiency due to menstrual iron losses and pregnancy.26

The US CDC has suggested that the ‘worldwide’ coverage of wheat flour fortification should be increased, with the goal of increasing iron and folic acid consumption. The worldwide coverage of wheat flour fortification increased from 18% in 2004 to 27% in 2007, and approximately 540 million people have had access to fortified wheat flour since 2007.29 However, according to the CDC, this improvement is insufficient and further increases are needed.

However, in order for this recommendation to be useful for developing countries with limited resources, policy-makers must ensure that flour fortification programmes have beneficial effects on the prevalence of anaemia/iron deficiency in such countries. The results of the present study in Iran showed that the coverage of fortified flour and bread was 90% and 98.7% in Bushehr; and 94.1% and 95% in Golestan, respectively. Regarding the findings of the process evaluation, particular attention needs to be paid to the flour fortification process in these provinces.

Notably, similar trends were found in the indicators of anaemia/iron deficiency among the studied women in both Bushehr province and Golestan province. The flour fortification programme appears to have had beneficial effects on ferritin levels (iron deficiency) in both provinces. The prevalence of iron deficiency in women of Bushehr province decreased from 22.2% in 2001 (pre intervention) to 15.7% in 2009, while that in women of Golestan province decreased from 26.7% in 2007 (pre intervention) to 14.6% in 2009. The pre-/post intervention prevalence of iron-deficiency anaemia was not significantly different in either of the provinces. Interestingly, the prevalence of anaemia (low haemoglobin) was significantly higher after the intervention in women from both Bushehr and Golestan provinces.

However, recent findings in countries such as Guatemala, Brazil, Sri Lanka and Venezuela have demonstrated that iron fortification appears to have little impact on anaemia. These findings have been attributed to the questionable magnitude of the iron-deficiency component of anaemia, and the potential low bioavailability of iron compounds in fortification programmes.30-35

The present study showed that the flour fortification programme in Iran only had a beneficial effect on the prevalence of iron deficiency in the studied women. The lack of apparent beneficial effects of this programme on the prevalence of anaemia may be due to low bio-availability of the iron used for fortification, the inhibitory effect of dietary components (e.g. phytate) on iron absorption, the relatively low iron content in the fortified flour, low consumption of other iron-containing foods (e.g. meat) and low consumption of fortified bread. The authors believe that some of the other important factors that diminish the beneficial effects of flour fortification on anaemia in Iran include parasitic and infectious diseases, and other diseases prevalent in these areas (e.g. minor thalassemias). The relatively low availability of other micronutrients (e.g. vitamin A) should not be ignored. Studies have shown that the prevalence of anaemia is high in developing countries affected by vitamin A deficiency, and improvement of vitamin A status has been shown to reduce anaemia.36-39 Therefore, the authors suggest other investigations to determine the effect of the above determinants as confounders to substantially reduce the prevalence of anaemia in Iran.

The results of the present study should be viewed in the light of an important limitation. The present study used a before-and-after design that implies no comparison with a control group. A field trial study design (with a control group) could not be used in the present study because flour fortification with iron has been expanded into all provinces in Iran. Despite this limitation, there are several findings that are worthy of discussion. The findings of the 2009 effectiveness evaluation in two pilot provinces (Bushehr and Golestan) and the findings of the 2007 effectiveness evaluations in Bushehr province were similar.

The authors believe that haemoglobin is not an adequate indicator for iron status in developing countries. Haemoglobin is the most commonly utilized indicator for diagnosis of anaemia, and by proxy as an indicator for iron-deficiency anaemia. Haemoglobin seems to be a more appropriate indicator in developed countries, because in many developing countries, anaemia is not only due to iron deficiency but also to other nutritional deficiencies, malaria, helminthes and other inflammatory/infectious diseases.21,40,41 Therefore, future studies should potentially use a combination of various biochemical indicators, such as measurement of haemoglobin, serum ferritin, erythrocyte protoporphyrin, transferrin saturation and transferrin receptors.42

In summary, this study found that the flour fortification programme in Iran is a useful component of a public health strategy aimed at improving iron-deficiency status. However, in areas where anaemia is not mainly due to iron deficiency, an iron fortification programme might decrease the prevalence of iron deficiency without affecting the prevalence of anaemia.

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References


