Public Health Nutrition: 16(5), 912–921 doi:10.1017/S1368980012004582

Modelling fortification of corn masa flour with folic acid and the potential impact on Mexican-American women with lower acculturation

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Submitted 20 March 2012: Final revision received 31 July 2012: Accepted 7 August 2012: First published online 1 November 2012

Abstract

Objective: Hispanics with lower acculturation may be at higher risk for neural tube defects compared with those with higher acculturation due to lower total folic acid intake or other undetermined factors. Modelling has indicated that fortification of corn masa flour with folic acid could selectively target Mexican Americans more than other race/ethnicities. We assessed whether fortification of corn masa flour with folic acid could selectively increase folic acid intake among Mexican-American women with lower acculturation, as indicated by specific factors (language preference, country of origin, time living in the USA).

Design: We used dietary intake and dietary supplement data from the National Health and Nutrition Examination Survey 2001–2008, to estimate the amount of additional total folic acid that could be consumed if products considered to contain corn masa flour were fortified at 140 μg of folic acid per 100 g of corn masa flour.

Setting: USA.

Subjects: Non-pregnant women aged 15–44 years (*n* 5369).

Results: Mexican-American women who reported speaking Spanish had a relative percentage change in usual daily total folic acid intake of 30·5 (95 % CI 27·8, 33·4) %, compared with 8·3 (95 % CI 7·3, 9·4) % for Mexican-American women who reported speaking English. We observed similar results for other acculturation factors. An increase of 6·0 percentage points in the number of Mexican-American women who would achieve the recommended intake of ≥400 μg folic acid/d occurred with fortification of corn masa flour; compared with increases of 1·1 percentage points for non-Hispanic whites and 1·3 percentage points for non-Hispanic blacks. An even greater percentage point increase was observed among Mexican-American women who reported speaking Spanish (8·2).

Conclusions: Fortification of corn masa flour could selectively increase total folic acid intake among Mexican-American women, especially targeting Mexican-American women with lower acculturation, and result in a decrease in the number of pregnancies affected by neural tube defects.

Keywords
Fortification
Corn masa flour
Acculturation
Folic acid

Randomized controlled trials have indicated that women who consume higher amounts of folic acid reduce their risk of having a pregnancy affected by neural tube defects (NTD)[1,2]. This led to recommendations by the US Public Health Service (1992) and the Institute of Medicine (1998) that women capable of becoming pregnant should consume 400 μg of folic acid every day[3,4]. The US Food and Drug Administration mandated that by 1998 cereal grain products labelled as enriched (e.g. breads, pastas) be fortified with 140 μg of folic acid per 100 g of flour in an effort to reduce the risk of NTD such as anencephaly and spina bifida among women of childbearing age[5]. Since mandatory folic acid fortification, the prevalence of NTD has decreased by 36 % in the USA[6]; however, the prevalence of NTD continues to be highest among Hispanic† women[6,8,9]. Mexican-American and non-Hispanic white women have reported similar folic acid intakes from cereal grain products labelled as enriched, but total folic acid intakes – which include cereal grain products labelled as

† The term 'Hispanic' is used for NTD because this is how the data are collected. However, folic acid intake data that can be generalized to the US population are available only for Mexican Americans. It should be noted that approximately 63 % of all Hispanics in the USA are Mexican Americans[7].

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enriched, ready-to-eat cereals (that can be voluntarily fortified up to 400 μg per serving[10]) and supplements containing folic acid – are lower among Mexican-American women[11]. The disparity among Mexican-American women is more pronounced when total folic acid intake is stratified by factors that assess acculturation among Mexican-American women (e.g. language preference, country of origin or time living in the USA)[11]. The association of acculturation, a term used to describe the process in which two cultures combine with one another[12], with the risk of NTD among the Hispanic population has been assessed. A recent case–control study found that the risk of spina bifida was higher among Hispanic women who reported speaking Spanish or reported being born in Mexico/Central America and residing in the USA for <5 years (i.e. proxies for lower acculturation) than among non-Hispanic white women[13].

Corn masa flour, an ingredient that is used to make corn tortillas but is not currently fortified with folic acid, is consumed in large quantities by the Mexican and Central American populations[14]. Hamner *et al.* modelled the potential impact that fortification of corn masa flour with folic acid could have on total folic acid intake in the Mexican-American population[15]. Results indicated that this intervention could selectively target the Mexican-American population more than other race/ethnicities[15]. However, their analysis did not differentiate Mexican Americans by acculturation status. The purpose of the current analysis was to assess whether fortification of corn masa flour could selectively target Mexican-American women with lower acculturation as defined by language preference, country of origin and time living in the USA.

Materials and methods

*National Health and Nutrition Examination Survey, 2001–2008**

The National Health and Nutrition Examination Survey (NHANES) 2001–2008 was conducted using a stratified multistage probability design. The survey captured a nationally representative sample of the non-institutionalized civilian US population. Participants completed a household interview and a physical examination. For the current analysis, we used data from NHANES 2001–2008 excluding women who were pregnant or those whose dietary interview data did not meet minimum required standards for data quality on day 1 or day 2[16]. Analyses conducted by race/ethnicity were restricted to non-Hispanic white, non-Hispanic black and Mexican-American women because of the small numbers of women of other racial and ethnic groups. All participants in NHANES provided written informed consent and the NHANES study received approval from the National Center for Health Statistics Ethical Review Board.

Modelling of folic acid intake from corn masa flour

Methods for modelling the impact of corn masa flour fortification on folic acid intake have been described previously[15]. In summary, modelling entailed four main steps: (i) identification of foods that could contain corn masa flour; (ii) determination of the proportion of corn masa flour per food item by weight; (iii) determination of the amount of additional folic acid in each food item from corn masa flour fortified at 140 μg of folic acid per 100 g of corn masa flour; and (iv) creation of modelled folic acid intake amounts with the additional folic acid intake from fortified corn masa flour.

As was done previously, foods reported in NHANES 2005–2008 were reviewed to identify those that could contain corn masa flour. An additional sixteen foods were added to the original foods identified and reported in 2001–2004[15] and were validated by an international manufacturer of corn masa flour, resulting in 103 foods (see Appendix).

Sample calculations to determine the proportion of corn masa flour in each food item and how much additional folic acid would be added to products that could contain corn masa flour if fortified are available in Hamner *et al.*[15]. The total amount of folic acid an individual would have consumed with folic acid fortification of corn masa flour included the estimated or expected intake from fortified corn masa flour as if it were fortified plus the actual reported folic acid intake from other foods and supplements.

Folic acid intake from foods

We obtained estimated intake of folic acid from foods using one 24 h dietary recall questionnaire in NHANES 2001–2002 and two 24 h dietary recall questionnaires for NHANES 2003–2008. To calculate nutrient intake from foods, we used the US Department of Agriculture Food and Nutrient Database for Dietary Studies version 1 for NHANES 2001–2002[17], version 2 for NHANES 2003–2004[18], version 3 for NHANES 2005–2006[19] and version 4·1 for NHANES 2007–2008[20].

Folic acid intake from supplements

During each household interview in NHANES 2001–2008, participants were asked about their use of dietary supplements over the past 30 d, including single vitamins, multivitamins, minerals, herbs and other similar nutritional substances, and were classified as a user if they reported taking such a supplement containing folic acid at least one time during the past 30 d. We calculated the average daily folic acid intake from each supplement and added this estimate to the amount of folic acid consumed

* The description of the Materials and methods was adapted directly from Hamner *et al.*[15]. The analysis presented here includes four additional survey years (2005–2008) and any methodology or analytical changes as a result of these additional years are noted.

from foods for each day of intake for each individual[21]. In calculating usual total folic acid intake, average folic acid intake from supplements was added to foods and then usual intake was estimated using the Software for Intake Distribution Estimation (PC-SIDE).

Acculturation factors

NHANES includes data on several factors that can be used to classify acculturation. These variables are available for participants aged 12 years and older. Among individuals who identified themselves as Hispanic, NHANES recorded the primary language spoken at home. As has been done previously[11], we categorized language spoken at home into three levels: (i) women who reported speaking English all or most of the time; (ii) women who reported speaking an equal amount of English and Spanish; and (iii) women who reported speaking Spanish all or most of the time. Individuals were categorized as being born in the USA or Mexico for country of origin. Information on length of time living in the USA was categorized into <5 years, 5–14 years or ≥15 years. For purposes of the current analysis, lower acculturation categories were defined by: (i) speaking Spanish all or most of the time; (ii) speaking an equal amount of Spanish and English; (iii) being born in Mexico; (iv) living in the USA for <5 years; or (v) living in the USA for 5–14 years. Acculturation factors were considered only for Mexican Americans.

Analytic sample

Of the 6210 non-pregnant women aged 15–44 years during the period 2001–2008, we excluded 778 women who did not meet the minimum data quality standard for dietary recall on day 1 (2001–2008) or day 2 of their dietary recall (2003–2008 only) because of incomplete dietary records. Additionally, we excluded women who were missing information on supplement use (*n* 63), resulting in a final sample size of 5369 non-pregnant women aged 15–44 years (86 % of the eligible sample). Compared with women included in the final analytic sample, to the extent data were available, excluded women were less likely to have reported consuming corn masa flour ($P < 0{\cdot}05$, χ^2 test); however, there were no differences by race/ethnicity or use of a folic acid-containing supplement.

Statistical analysis

We conducted analyses using usual daily total folic acid intake without and with the modelled addition of folic acid from corn masa flour fortification (referred to as 'current' and 'modelled', respectively, in the presentation of results) to assess the potential contribution that fortified corn masa flour could have on total folic acid intake. It has been reported that estimates of nutrient intake based on one day's worth of intake do not account for possible within-person variation, resulting in an overestimation of the variance in intake of a population[19,20]. Therefore, we used PC-SIDE version 1·02 (Iowa State University, Ames, IA, USA), which takes into account both between- and within-person variation when at least a sub-sample of the population has two or more days of intake data, as in NHANES 2001–2008, to estimate usual nutrient intake. Within-person variation estimates from NHANES 2003–2008 were used as an estimate for within-person variation in NHANES 2001–2002 data. Detailed descriptions of this method are published elsewhere[22,23].

We used PC-SIDE to estimate the distributions (percentiles) of usual daily total folic acid intake, as well as daily total energy intake. We estimated the percentage of a given population with usual daily total folic acid intake at or above the recommended 400 μg of total folic acid. Analyses were conducted for all women aged 15–44 years, and stratified by race/ethnicity and acculturation factors. We used PC-SIDE to estimate the best linear unbiased predictor of usual daily total folic acid intake for each individual. The best linear unbiased predictors were used to estimate the relative percentage change between the median intake under the current scenario and the modelled scenario in which corn masa flour was fortified as described in Hamner *et al.*[15].

We used SPSS Complex Samples Design version 18·0 to account for the survey design and to calculate all frequencies, *t* tests, χ^2 tests and relative percentage changes. We conducted all analyses using 8-year dietary weights calculated from day 1 dietary weights for the period 2001–2002 and day 2 dietary weights for the period 2003–2008, as recommended by the National Center for Health Statistics at the Centers for Disease Control and Prevention[16]. For analyses conducted with PC-SIDE, we calculated standard errors using a set of 122 jackknife replicate weights. Replicate weights were calculated using a combination of day 1 dietary weights for NHANES 2001–2002 data and day 2 dietary weights for NHANES 2003–2008.

Results

Demographic characteristics of the sample are presented in Table 1. Mexican-American women were more likely to report consuming corn masa flour on either day 1 or day 2 of the survey as compared with non-Hispanic white women or non-Hispanic black women (67·2 %, 27·6 % and 29·6 %, respectively; $P < 0{\cdot}05$). Demographic characteristics of Mexican-American women by acculturation factors are reported in Table 2. Mexican-American women who reported lower acculturation factors were more likely to report consuming corn masa flour on either day 1 or day 2 of the survey as compared with Mexican-American women who reported higher acculturation factors ($P < 0{\cdot}05$). All percentages are weighted.

Estimates of current and modelled median usual daily intake of total folic acid for women of childbearing age are presented in Table 3. The current overall median usual

Table 1 Demographic characteristics of women aged 15–44 years by race/ethnicity, NHANES 2001–2008

	Total			Non-Hispanic white‡			Non-Hispanic black‡			Mexican American‡		
	Unweighted *n*	%	95 % CI	Unweighted *n*	%	95 % CI	Unweighted *n*	%	95 % CI	Unweighted *n*	%	95 % CI
Women aged 15–44 years (%)	5369	–	–	2065	65·9	61·8, 69·8	1384	13·5	11·3, 16·2	1362	10·0	8·4, 11·9
Folic acid supplement use§ (%)	1292	31·6	29·1, 34·2	720	37·1*	33·3, 41·0	223	18·7*	15·1, 23·0	221	19·1*	15·9, 22·8
Folic acid intake from supplements‖,¶ (μg/d)	–	380	357, 403	–	391	364, 419	–	315†	255, 374	–	345	272, 418
Consumption of corn masa flour** (%)	2083	32·0	29·9, 34·2	589	27·6*	25·1, 30·3	413	29·6*	26·2, 33·3	906	67·2*	63·0, 71·2
Usual energy intake†† (kJ/d)	5369	7908	7518, 8297	2065	7971	7514, 8427	1384	7945	7682, 8209	1362	8000	7460, 8540

NHANES, National Health and Nutrition Examination Survey.
*Significantly different by race/ethnicity (Pearson χ^2 test): $P<0{\cdot}05$.
†Significantly different non-Hispanic whites *v.* non-Hispanic blacks (*t* test): $P<0{\cdot}05$.
‡Race/ethnicity sub-analyses were restricted to non-Hispanic whites, non-Hispanic blacks and Mexican Americans.
§Reported folic acid supplement use is defined as consuming a supplement containing folic acid in the previous 30 d.
‖Reported folic acid supplement use is among supplement users only.
¶Values are mean and 95 % confidence interval.
**Reported consumption of corn masa flour is defined as consuming products that could contain corn masa flour on either day 1 or day 2 of the survey.
††Values are median and interquartile range.

Table 2 Demographic characteristics of Mexican-American women aged 15–44 years by acculturation factors‡, NHANES 2001–2008

	Language preference						Country of origin				Time in the USA					
	Spanish all or most of the time		Equal Spanish and English		English all or most of the time		Mexico		USA		<5 years		5–14 years		≥15 years	
	%	95 % CI	%	95 % CI	%	95 % CI	%	95 % CI	%	95 % CI	%	95 % CI	%	95 % CI	%	95 % CI
Total (%)	49·6	44·9, 54·4	15·4	12·6, 18·7	34·9	30·9, 39·2	51·4	45·1, 57·6	48·3	42·1, 54·6	12·1	8·9, 16·3	22·8	19·2, 26·9	65·1	60·1, 69·8
Unweighted *n*	615		253		493		648		712		173		275		904	
Folic acid supplement use§ (%)	13·8*	10·1, 18·6	14·0	8·4, 22·4	28·8	22·0, 36·8	15·2*	12·1, 18·8	23·3	18·2, 29·5	8·3*	5·3, 12·6	16·5	11·2, 23·6	22·2	17·7, 27·6
Folic acid intake from supplements‖,¶ (μg/d)	356	274, 438	381	198, 563	329	219, 440	360	279, 441	335	234, 435	224†	83, 366	358	291, 424	350	260, 439
Consumption of corn masa flour** (%)	78·5*	74·3, 82·2	66·5	56·3, 75·3	51·4	44·0, 58·8	79·5*	75·1, 83·3	54·0	47·1, 60·8	77·9*	68·9, 84·9	83·7	77·1, 88·6	59·2	53·9, 64·3
Usual energy intake†† (kJ/d)	7753	7084, 8422	8975	7820, 10 129	7983	7104, 8862	7837	7414, 8529	8230	7351, 9109	7916	6414, 9418	7908	7309, 8506	8067	7075, 9058

NHANES, National Health and Nutrition Examination Survey.
*Significantly different by acculturation factor (Pearson χ^2 test): $P<0{\cdot}05$.
†Significantly different <5 years *v.* 5–14 years and <5 years *v.* ≥15 years (*t* test): $P<0{\cdot}05$.
‡Acculturation sub-analyses were restricted to Mexican Americans. Unweighted *n* might not add up to total number of Mexican-American women because of missing data in acculturation factors.
§Reported folic acid supplement use is defined as consuming a supplement containing folic acid in the previous 30 d.
‖Reported folic acid supplement use is among supplement users only.
¶Values are mean and 95 % confidence interval.
**Reported consumption of corn masa flour is defined as consuming products that could contain corn masa flour on either day 1 or day 2 of the survey.
††Values are median and interquartile range.

Table 3 Median usual daily total folic acid intake with (modelled) and without (current) folic acid fortification of corn masa flour for women aged 15–44 years by race/ethnicity and age, NHANES 2001–2008‡

		Current usual intake (μg/d)		Modelled usual intake (μg/d)		Relative percentage change§ (%)	
	Unweighted *n*	Median	95 % CI	Median	95 % CI	Median	95 % CI
Total	5369	244	230, 258	257	244, 270	3·7	3·1, 4·2
Race/ethnicity‖							
Non-Hispanic white	2065	263	239, 287	274	248, 300	3·9	3·3, 4·4
Non-Hispanic black	1384	186	155, 217	197	163, 231	4·6	4·1, 5·1
Mexican American	1362	202	167, 237	243	209, 277	21·0	18·7, 23·3
Acculturation factors¶							
Language preference							
Spanish all or most of the time	615	191	146, 236	247	205, 289	30·5	27·8, 33·4
Equal Spanish and English	253	185	151, 219	225	189, 261	22·0	20·2, 23·8
English all or most of the time	493	218	154, 282	241	186, 296	8·3	7·3, 9·4
Country of origin							
Mexico	648	196	154, 238	252	210, 294	29·9	26·9, 33·0
USA	712	210	180, 240	234	208, 260	10·8	9·2, 12·3
Time living in the USA							
<5 years	173	161	122, 200	230	186, 274	45·1	39·7, 50·7
5–14 years	275	205	154, 256	271	207, 335	33·7	29·7, 37·8
≥15 years	904	210	174, 246	239	200, 278	13·1	11·3, 15·0

NHANES, National Health and Nutrition Examination Survey.
‡Data are adjusted for intake day of the week and interview method (in person or by telephone).
§The relative percentage change was the antilog of the difference in the log of modelled intake minus the log of the current intake.
‖Race/ethnicity sub-analyses were restricted to non-Hispanic whites, non-Hispanic blacks and Mexican Americans.
¶Acculturation sub-analyses were restricted to Mexican Americans. Unweighted *n* might not add up to total number of Mexican-American women because of missing data in acculturation factors.

daily intake of total folic acid was 244 (95 % CI 230, 258) μg, which could increase to 257 (95 % CI 244, 270) μg with fortification of corn masa flour. This represents a relative percentage change of 3·7 (95 % CI 3·1, 4·2) %.

Non-Hispanic white women had higher (263 (95 % CI 239, 287) μg) current median usual daily intake of total folic acid than either non-Hispanic black women (186 (95 % CI 155, 217) μg) or Mexican-American women (202 (95 % CI 167, 237) μg). In addition, non-Hispanic white women had higher modelled median usual daily intake of total folic acid than either non-Hispanic black women or Mexican-American women (274 (95 % CI 248, 300) μg, 197 (95 % CI 163, 231) μg and 243 (95 % CI 209, 277) μg, respectively). Mexican-American women had the largest absolute and relative percentage increases, with 41 μg and 21·0 %, respectively, compared with non-Hispanic white women (11 μg and 3·9 %, respectively) and non-Hispanic black women (11 μg and 4·6 %, respectively).

Mexican-American women who reported lower acculturation factors had lower current median usual daily intake of total folic acid than Mexican-American women who reported higher acculturation factors. These differences were attenuated with fortification of corn masa flour. Mexican-American women who reported speaking Spanish all or most of the time had current median usual daily intake of total folic acid of 191 (95 % CI 146, 236) μg and those who reported speaking English all or most of the time had current median usual daily intake of total folic acid of 218 (95 % CI 154, 282) μg. With fortification of corn masa flour, the modelled median usual daily intake of total folic acid for Mexican-American women who reported speaking Spanish all or most of the time could increase by 56 μg to 247 (95 % CI 205, 289) μg, while for those who reported speaking English all or most of the time the modelled median usual daily intake of total folic acid could increase by half that amount, 23 μg, to 241 (95 % CI 186, 296) μg. The relative percentage change for Mexican-American women who reported speaking Spanish all or most of the time was 30·5 (95 % CI 27·8, 33·4) %, compared with an 8·3 (95 % CI 7·3, 9·4) % relative percentage change for Mexican-American women who reported speaking English all or most of the time. Similar relative percentage changes were observed for Mexican-American women with lower acculturation (i.e. women who reported speaking equal Spanish and English, in the USA for <5 years, in the USA for 5–14 years and born in Mexico).

We estimated the percentage of women of childbearing age with usual daily total folic acid intake at or above the recommended 400 μg for current and modelled folic acid intake levels (Table 4). Among all women aged 15–44 years, 24·0 (95 % CI 21·4, 26·7) % had usual daily intake of total folic acid ≥400 μg under the current scenario, which could increase to 26·0 (95 % CI 23·4, 28·6) % with fortification of corn masa flour. Mexican-American women had a much larger increase in the percentage of women achieving the recommendation for total folic acid. An estimated 13·0 (95 % CI 7·8, 18·2) % of Mexican-American women were consuming ≥400 μg of total folic acid/d under the current scenario, which could increase to 19·0 (95 % CI 11·1, 26·8) %, an increase of 6·0 percentage points, with

Table 4 Percentage of women aged 15–44 years who would achieve the recommended intake of total folic acid (400 μg/d) with (modelled) and without (current) folic acid fortification of corn masa flour by race/ethnicity and acculturation factors, NHANES 2001–2008‡

		Current usual intake (≥400 μg of total folic acid/d)		Modelled usual intake (≥400 μg of total folic acid/d)	
	Unweighted (*n*)	%	95 % CI	%	95 % CI
Total	5369	24·0	21·4, 26·7	26·0	23·4, 28·6
Race/ethnicity§					
Non-Hispanic white	2065	29·6	25·7, 33·4	30·7	26·6, 34·8
Non-Hispanic black	1384	10·3	6·7, 14·0	11·6	6·7, 16·6
Mexican American	1362	13·0	7·8, 18·2	19·0	11·1, 26·8
Acculturation factors‖					
Language preference					
Spanish all or most of the time	615	9·2	5·6, 12·9	17·4*	10·0, 24·9
Equal Spanish and English	253	4·5	0, 10·4	10·3	0·8, 19·8
English all or most of the time	493	20·3	7·3, 33·3	22·9	9·2, 36·6
Country of origin					
Mexico	648	11·1	6·1, 16·0	19·5	10·1, 28·9
USA	712	15·3	8·1, 22·4	18·6	12·4, 24·8
Time living in the USA					
<5 years	173	5·0	0, 13·2	11·2	3·4, 19·0
5–14 years	275	10·5	2·2, 18·7	23·0	4·6, 41·4
≥15 years	904	14·6	6·3, 22·8	18·7	10·2, 27·3

NHANES, National Health and Nutrition Examination Survey.
*Significantly different current *v.* modelled (*t* test): $P < 0{\cdot}05$.
‡Data are adjusted for intake day of the week and interview method (in person or by telephone).
§Race/ethnicity sub-analyses were restricted to non-Hispanic whites, non-Hispanic blacks and Mexican Americans.
‖Acculturation sub-analyses were restricted to Mexican Americans. Unweighted *n* might not add up to total number of Mexican-American women because of missing data in acculturation factors.

fortification of corn masa flour. Comparatively, non-Hispanic white women could have a 1·1 percentage point increase in the percentage with intake of total folic acid ≥400 μg/d (current: 29·6 (95 % CI 25·7, 33·4) %; modelled: 30·7 (95 % CI 26·6, 34·8) % and non-Hispanic black women could have a 1·3 percentage point increase (current: 10·3 (95 % CI 6·7, 14·0) %; modelled: 11·6 (95 % CI 6·7, 16·6) %).

Generally, Mexican-American women who had lower acculturation factors tended to have a larger increase in the percentage with usual daily intake of total folic acid ≥400 μg with fortification of corn masa flour. Among Mexican-American women who reported speaking Spanish all or most of the time, 9·2 (95 % CI 5·6, 12·9) % were achieving the recommendation for total folic acid under the current scenario, and this could increase by 8·2 percentage points to 17·4 (95 % CI 10·0, 24·9) % with fortification of corn masa flour, a statistically significant increase ($P = 0{\cdot}026$). Comparatively, among Mexican-American women who reported speaking English all or most of the time, 20·3 (95 % CI 7·3, 33·3) % were achieving the recommendation for total folic acid under the current scenario, which could increase by 2·6 percentage points to 22·9 (95 % CI 9·2, 36·6) % with fortification of corn masa flour. When stratified by country of origin and time living in the USA, Mexican-American women who reported being born in Mexico or living in the USA for <5 years or 5–14 years had larger percentage point increases for achieving the recommendation for total folic acid intake, as compared with their higher acculturated counterparts, with fortification of corn masa flour.

Discussion

The current analysis builds on the earlier modelling exercise from Hamner *et al.*[15] and assesses the impact of fortification of corn masa flour with folic acid on the segments of the Mexican-American population with the lowest folic acid intake[11] and the highest prevalence of NTD-affected pregnancies, namely Mexican-American women with lower acculturation[6,8,9,13,24,25]. Overall, the modelling suggests that fortification of corn masa flour could substantially increase the total folic acid intake among Mexican-American women with lower acculturation compared with those with higher acculturation. Disparities in total folic acid intake between Mexican-American and non-Hispanic white women and between Mexican-American women with lower *v.* higher acculturation could be lessened if corn masa flour is fortified at 140 μg of folic acid per 100 g of corn masa flour. Additionally, fortification of corn masa flour could shift the population distribution of total folic acid intake and could increase the percentage of women of childbearing age with usual daily intake of total folic acid ≥400 μg, with a larger increase among Mexican-American women with lower acculturation. Ultimately, this public health intervention could lead to a reduction in the risk of NTD for Hispanics.

Our analysis is subject to several limitations. The measurement of acculturation was based on individual questions and not from a validated acculturation scale. However, researchers have found that language preference can explain the majority of variation in validated scales[26,27], making this a reasonable proxy measure. We could only

estimate which foods could contain corn masa flour because this commodity was not specifically available in the MyPyramid Equivalents database. However, these foods were independently validated by a manufacturer of corn masa flour. The amount of folic acid added to each food was based on a fortification level which would result in a final product containing 140 μg per 100 g of corn masa flour and with the assumption that all products that could contain corn masa flour were fortified at this amount. Estimates did not take into account any losses in folic acid level that might occur in corn masa flour during processing; thus, these estimates might be an overestimate of folic acid intake.

According to the 2010 US Census, there are over 50 million individuals in the USA who report being of Hispanic or Latino origin; 63% of these individuals are Mexican American[7]. Based on data from 2005–2009, the population of Hispanic women of childbearing age is also increasing, with over 10 million Hispanic women aged 15–44 years[28]. Hispanic women accounted for approximately 1 million births in the USA in 2008[29]. Further, Hispanic women have higher birth rates, higher fertility rates, are younger at first pregnancy and have children at a later age than their non-Hispanic counterparts[29]. Although the prevalence of NTD has decreased in the USA since mandatory folic acid fortification[6] and the disparity in NTD prevalence between Hispanic women and non-Hispanic white women has lessened, data indicate that Hispanic women continue to have the highest risk of having an NTD-affected pregnancy[6,8]. Using data from twenty-five population-based surveillance systems from 2005–2007, Hispanic women were estimated to be 1·21 (95% CI 1·11, 1·31) times more at risk for an NTD-affected pregnancy than non-Hispanic white women[6]. Other researchers have also suggested that acculturation could be a risk factor for NTD[13,24,25]. However, this relationship has not been reported consistently and has been shown to vary for other birth defects[24]. Mexican-American women, and specifically those with lower acculturation, have lower total folic acid intake than non-Hispanic white women[11]. Given that the number of Hispanic women is increasing, that these women have a higher pregnancy rate, birth rate and risk of NTD, and that Mexican-American women, specifically those with lower acculturation, have a lower total folic acid intake and possibly are at higher risk for NTD, fortification of corn masa flour with folic acid could have a significant public health impact. For example, an additional 6% of Mexican-American women consuming the recommended amount of folic acid means that almost 422 000 women could be impacted[28]. Given these disparities and the potential for a large number of women to be affected, providing another opportunity for Hispanic women, and in particular for Hispanic women with lower acculturation, to consume folic acid could lessen the number of pregnancies affected by these serious birth defects.

In the current analysis, we estimated that Mexican-American women with lower acculturation were more likely to report consuming corn masa flour products than those with higher acculturation, resulting in the most vulnerable group of Mexican-American women being selectively targeted by a corn masa flour fortification initiative. Higher consumption of corn masa flour products among less acculturated Mexican Americans could be the result of having similar eating patterns to their native culture, which relies heavily on corn masa flour products such as corn tortillas[14]. Mexican Americans who are more acculturated may be more likely to have eating patterns that are more similar to the dominant US culture, which relies less heavily on corn masa flour products[30–32].

Previous public health campaigns targeting Hispanic women have proved to be difficult and costly. There is evidence that paid media and health education/communication campaigns targeting Spanish-speaking Hispanic women resulted in only small increases in women's consumption of a folic acid supplement[33]. Other interventions include the use of promotoras, or lay community health workers, in an effort to reach women on a one-to-one basis[34,35]. However, paid campaigns such as these are costly, difficult to sustain and localized in scope and geographic area. Thus, public health professionals need to utilize other possible interventions, such as fortification, to increase total folic acid intake without requiring behaviour changes.

Fortification of corn masa flour is a policy-level intervention that would not require sustained behaviour change and could result in a decreased prevalence of NTD. Given that the estimated total lifetime direct cost of a child born with spina bifida is $US 560 000 (2003 dollars)[36], additional babies being born healthy could provide substantial financial return on investment to fortify corn masa flour with folic acid. Regardless of financial considerations, spina bifida is a debilitating lifelong condition placing a severe health and emotional burden on those affected and their families[37].

Conclusions and recommendations

Fortification of corn masa flour with folic acid could selectively target Mexican-American women, particularly those with lower acculturation factors. Fortification of corn masa flour could reduce the disparity in total folic acid intake between Mexican-American women with lower and higher acculturation, shift the distribution of total folic acid intake, and ensure that more women achieve the recommended intake of 400 μg of folic acid every day to prevent NTD. Fortification of corn masa flour is a policy-level intervention with the potential for significant public health impact.

Acknowledgements

Sources of funding: The research was funded by the US Centers for Disease Control and Prevention. The findings

and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention. *Conflicts of interest:* The authors report no conflicts of interest. *Authors' contributions:* Each author contributed to the development of this work. H.C.H. and S.C.T. designed the research; H.C.H. and S.C.T. analysed the data and performed the statistical analysis; H.C.H. and S.C.T. wrote the paper. H.C.H. had primary responsibility for final content. All authors have read and approved the final manuscript.

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Appendix

Foods considered to contain corn masa flour, NHANES 2001–2008

Tortilla, corn
Taco shell, corn
Cracker corn (includes stoned corn cracker)
Salty snacks, corn/cornmeal base, nut/nut toasted
Salty snacks, corn or cornmeal, corn chips, cheese
Salty snacks, corn or cornmeal, corn puffs, twists
Salty snacks, corn or cornmeal, tortilla chips
Salty snacks, corn/corn-cheese chips, unsalted
Salty snacks, corn/cornmeal base, tortilla chips light
Salty snacks, tortilla chips, fat free, with Olean
Salty snacks, corn/cornmeal base, tortilla, low fat, baked
Salty snacks, corn/cornmeal, tortilla, low fat, baked, no salt
Salty snacks, corn/cornmeal base, with oat bran, tortilla chips
Salty snacks, corn based/cheese puffs & twists, low fat
Tortilla chips, unsalted
Corn flour patties or tarts, fried
Nachos with beef, beans, cheese & sour cream
Nachos with cheese & sour cream
Nachos with cheese, meatless, no beans
Nachos with beans, no cheese
Nachos with beans & cheese
Nachos with beef, beans & cheese
Nachos with beef & cheese
Nachos with chilli
Nachos with beef, beans, cheese, tomatoes & onions
Nachos with chicken/turkey & cheese
Enchilada with beef, no beans
Enchilada with beef & beans (includes enchilada, not further specified)
Enchilada with beef, beans & cheese
Enchilada with beef & cheese, no beans
Enchilada with ham & cheese, no beans
Enchilada with chicken, tomato-base sauce
Enchilada with chicken & beans, tomato-base sauce
Enchilada with chicken, beans & cheese, tomato-base sauce
Enchilada with chicken & cheese, no beans, tomato-base sauce
Enchilada with beans, meatless
Enchilada with beans & cheese, meatless
Enchilada with cheese, meatless, no beans
Enchilada with seafood, tomato sauce
Beef enchilada dinner, not further specified (frozen meal)
Beef enchilada, gravy, rice, refried beans (frozen)
Cheese enchilada with beans & rice (frozen meal)
Cheese enchilada (frozen meal)
Chicken enchilada (diet frozen meal)
Chicken enchilada with salsa, rice, vegetables, dessert (diet frozen)
Chilaquiles, tortilla casserole with salsa, cheese & egg
Chilaquiles, tortilla casserole, no egg
Pochito (frankfurter/hot dog & beef chilli in tortilla)
Huevos rancheros
Mexican casserole with beef & beans
Mexican casserole with beef (includes frito pie, not further specified)
Sopa de tortilla, Mexican-style tortilla soup
Tamale with meat &/or poultry (includes tamale, not further specified)
Tamale, meatless, Caribbean or Puerto Rican style
Tamale, plain, meatless, no sauce, Mexican
Tamale casserole with meat
Tamale casserole, Puerto Rican (*tamales en cazuela*)
Tamale in a leaf, Puerto Rican (*tamales en hoja*)

Continued

Tamale, sweet
Tamale, sweet, with fruit
Tamale with meat
Tamale with chicken
Tamale, plain, meatless, no sauce, Puerto Rican style
Pupusa, cheese-filled
Pupusa, meat-filled
Pupusa, bean-filled
Chalupa with beans, cheese, lettuce & tomato
Chalupa with beef, cheese, lettuce, tomato & sour cream
Chalupa with beef, cheese, lettuce, tomato & salsa
Chalupa with beans, chicken & cheese
Chalupa with chicken, cheese, lettuce, tomato & sour cream
Chalupa with chicken, cheese, lettuce, tomato & salsa
Gordita/sope shell, plain no filling, grill, no fat added
Gordita/sope shell, plain, no filling, fried in oil
Quesadilla with cheese, meatless
Quesadilla with meat & cheese
Quesadilla with poultry & cheese
Taco/tostada with beef, cheese & lettuce
Taco/tostada with beef, lettuce, tomato & salsa
Taco/tostada with beef, cheese, lettuce, tomato & salsa
Taco with beef, cheese, lettuce, tomato & sour cream
Soft taco with beef, cheese & lettuce (includes Taco Bell)
Soft taco with chicken, cheese & lettuce
Soft taco with chicken, cheese, lettuce, tomato & sour cream
Taco/tostada with chicken/turkey, lettuce, tomato & salsa
Soft taco with beef, cheese, lettuce, tomato & salsa
Soft taco with bean, cheese & lettuce
Soft taco with bean, cheese, lettuce, tomato &/or salsa
Soft taco with bean, cheese, lettuce, tomato &/or salsa, sour cream
Taco/tostada with fish
Taco/tostada with chicken, cheese, lettuce, tomato & salsa
Taco/tostada with beans, meatless, lettuce, tomato & salsa
Taco/tostada with beans, cheese, lettuce, tomato & salsa
Taco/tostada with beans, cheese, meat, lettuce, tomato & salsa
Taco salad with beef & cheese, corn chips
Flauta, not further specified
Flauta with beef
Flauta with chicken
Taquitos
Taquitos with meat
Taquitos with chicken
Taco with crab meat, Puerto Rican (*tacos de jueyes*)
Atole (cornmeal beverage)

NHANES, National Health and Nutrition Examination Survey.