Maternal consumption of *pulque*, a traditional central Mexican alcoholic beverage: relationships to infant growth and development

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Abstract

Objectives: To document the consumption during pregnancy of *pulque*, a traditional central Mexican alcoholic beverage, and its relationship to subsequent infant size, physical growth and performance on the Bayley Scales of Infant Development.

Design: Prospective cohort study.

Setting: Six villages in rural, central Mexico in 1984–1985.

Subjects: Seventy mother–infant pairs.

Results: Most women (72.9%) consumed *pulque* during pregnancy, and 28.6% consumed more than 150 g ethanol week^{-1} from the beverage. Individuals who consumed *pulque* showed no compensating decrease in energy obtained from other foods. *Pulque* consumption possessed curvilinear relationships with both infant length (at 1 and 6 months) and Bayley mental performance (at 6 months). Heavy *pulque* intakes were associated with smaller infant size and poorer mental performance. In modest quantities, *pulque* consumption may have been beneficial due to its micronutrient content.

Conclusions: Intakes of alcohol from *pulque* were common among pregnant women in these rural, central Mexican villages. Given current scientific knowledge of the adverse effects of ethanol on foetal development, public health interventions are needed to reduce heavy *pulque* consumption during pregnancy in some areas of rural Mexico.

Alcoholic beverages comprise an important part of diets throughout much of the world. In the industrialised countries, alcohol often provides 10% or more of adult energy intakes[1]. Alcoholic beverages, if not distilled or overly processed, can also provide significant amounts of vitamins and minerals. Therefore, where micronutrient intakes are marginal, as is often the case in the developing countries, alcoholic beverages can be nutritionally significant[2].

Pulque, a beverage brewed from the sap of several *Agave* species, has long been a staple of the central Mexican diet[3,4]. For centuries, the mildly alcoholic beer (~4–6% ethanol by volume) has been regarded as healthy when consumed in moderation, and as possessed of medicinal qualities[5]. Indeed, *pulque* can provide important quantities of ascorbic acid, iron, and riboflavin – all nutrients consumed in low amounts by many individuals living in rural, central Mexico[6–9]. *Pulque* also contains significant quantities of steroidal saponins, many of which are bioactive[10]. Saponins present in *Agave* species have shown hypocholesterolemic, anti-inflammatory and antibiotic activity, but the functional effects of those in *pulque* remain unexplored[11–13]. Contrary to popular belief, *pulque* does not appear to contain psychoactive substances[14].

Ethanol consumption during pregnancy can adversely affect child growth and development[15,16]. Foetal Alcohol Syndrome (FAS), a dramatic effect of foetal ethanol exposure, is characterised by a triad of disordered growth, facial abnormalities and behavioural/cognitive impairments[1,17]. More common and less frequently diagnosed are Alcohol-Related Birth Defects (ARBD) and Foetal Alcohol Effects (FAE). The latter represent a broad spectrum of negative outcomes that fall short of classic

FAS, but which include adverse effects on growth, cognitive performance and behaviour[16].

In the developing countries, impaired child growth and development often occurs independently of any effect of alcohol. The World Health Organization estimates that 32.5% of children in the developing countries are 'stunted' (defined as stature falling <2 standard deviations (SD) below the median on standard growth curves)[18]. This stunting is often associated with adverse neurobehavioural outcomes[19,20]. Because in the developing countries foetal alcohol exposure often occurs within a biological and social environment that fails to permit optimal child growth and development, even in the absence of alcohol intake, maternal alcohol consumption in such populations has a particularly strong potential to directly and indirectly compromise child growth and development.

The current paper describes *pulque* consumption in a rural area of the central Mexican highlands. Subjects are 70 pregnant women and their subsequent infants. Because little has been written about *pulque* consumption during pregnancy, the paper describes in some detail: (1) patterns of drinking; (2) the contribution of *pulque* consumption to nutrient intake in pregnancy; and (3) the relationships of *pulque* intake during pregnancy to infant size, growth, and Bayley motor and mental performance.

Subjects and methods

The Mexico Nutrition CRSP
Data were collected as part of the Mexico NCRSP (Collaborative Research and Support Program on Human Nutrition), a prospective cohort study focused on the effects of marginal malnutrition on human function. The project was a collaboration between the University of Connecticut and the Instituto Nacional de la Nutrición Salvidor Zubirán (INNSZ) in Mexico City[21]. Project protocols were approved at both institutions by committees on the use of human subjects in research.

Research setting
Fieldwork was conducted between 1982 and 1986 in six small villages in the Solís Valley, a rural area in the central Mexican highlands at altitude of approximately 2400 m. Located about 100 km north-west of Mexico City, the predominant local economic activities were subsistence maize farming and low-skill wage labour. Household incomes were often supplemented by cash earned in Mexico City and other urban centres.

Subjects
From November 1984 to December 1985, 115 singleton births occurred in the six NCRSP villages. At 6 months of age, 89 (77.4%) infants were assessed by a project psychologist using the Bayley Scales of Infant Development[22]. This paper presents data on a subset of 70 mother–infant pairs with infant weight and length measures at 1 month, and at least 4 days of maternal dietary data collected during pregnancy. Subjects ($N = 70$) and non-subjects ($N = 45$) did not differ significantly by gender, community, household material wealth, household size, maternal education, or the proportion of time the male was present in the household. In this population, infants and young children were generally breast-fed. Complementary feeding usually began after 3 months of age.

Anthropometry
A project physician closely supervised and standardised all anthropometric measurements[23]. Maternal measures were collected either at the Solís Clinic or at home, and were scheduled once per month during pregnancy and the postnatal period. Infant anthropometry was scheduled for collection at birth, 8 days, 30 days, and once per month until age 8 months. Infants born at the Solís Clinic were weighed on a Salter infant scale, while older infants and infants born at home were weighed on a battery-operated digital scale (accurate to 0.1 kg). Infant lengths were measured with a steel tape; wooden blocks were used to locate the top of the head and bottom of the feet. A SAS program employing algorithms published by Dibley *et al.* was used to calculate weight-for-age, length-for-age and weight-for-length Z-scores[24]. Growth was measured as residual size when 6-month weight or length was regressed on 1-month weight or length[25].

Bayley Scales of Infant Development
A single, trained project psychologist (EM) assessed infants at 6 months of age using the Bayley Scales of Infant Development[22]. Based on the age of the children, the examiner used 51 Mental Scale (MDI) items (items 40–90) and 26 Motor Scale (PDI) items (items 15–40). All Bayley assessments were conducted at a single session in the infant's home. Bayley motor and mental scores are presented both as raw scores and as scores adjusted for age using the Bayley 'norms' – the MDI (mental scale) and PDI (motor scale).

Infant and maternal diets
Staff nutritionists assessed dietary intake by a combination of dietary recall, food record and food weighing during two consecutive 24-hour periods per month[21]. Maternal data were collected beginning at enrolment in the study (soon after pregnancy was identified) until 8 months postpartum. Daily nutrient intakes were estimated using the UCB International Minilist, a nutrient database created specifically for use by the Nutrition CRSP[26]. Summary dietary variables are means of daily intakes. Mothers had a mean of 9.9 ± 5.5 days of dietary data in pregnancy, and 11.2 ± 2.0 days postpartum.

Table 1 The Mexican Recommended Dietary Intakes (RDI) during pregnancy for selected nutrients, and the nutrient content of 0.5 litre of *pulque*, which was the median quantity consumed per sitting by the sample of 70 women

	Content per 0.5 litre			
	Mexican Food Tables*	Sanchez-Marroquin[29]	Mexican RDI†	% of RDI per 0.5 litre
Energy (kcal)	215	NA‡	2385	9.0
Ethanol (g)	23.5§	14.5–32.5	–	–
Ascorbic acid (mg)	30	NA‡	70	42.9
Thiamin (mg)	0.1	0.025–0.145	1.5	6.7
Riboflavin (mg)	0.1	0.090–0.165	1.7	5.9
Iron (mg)	3.5	NA‡	24	14.6

* Source: Hernandez *et al.*[6].
† Source: Instituto Nacionál de la Nutrición Salvidor Zubirán[36].
‡ NA = not available.
§ Value not provided in Mexican Food Tables, but based on the midpoint of the range of ethanol values (47 g l⁻¹) provided by Sanchez-Marroquin[29].

Nutrients, ethanol and pulque consumption

Information on the nutrient content of *pulque* derives from work done 50 years ago by Cravioto *et al.*[27,28]. In 1977, Sanchez-Marroquin[29] (cited by Steinkraus[5]) provided additional information on the alcohol, B-vitamin and amino acid content of *pulque* in the form of ranges, and showed the nutrient content of *pulque* to be highly variable when produced by traditional, small-scale methods (Table 1). The Cravioto values[27,28] continue to be those employed in the Mexican Food Composition Tables[6], and provide the basis for the values presented in this paper.

Ethanol intakes were estimated from the dietary intake data. For these 70 women, all ethanol came from *pulque*. Daily alcohol intakes were calculated using a value of 47 g of ethanol l⁻¹ of *pulque*, the midpoint of the range (29–65 g l⁻¹) provided by Sanchez-Marroquin[29]. *Pulque* consumption during pregnancy and lactation is presented as mean energy intake per recall day, and mean alcohol intake per week. Other alcohol intake variables are (1) mean intake per drinking day, (2) mean intake per 'drinking event', (3) the percentage of days drinking, and (4) the mean number of drinking events per drinking day. In the text, *pulque* consumption refers to mean intake across all recall days unless otherwise stated.

Blood collection and analysis

Blood data, collected during the third trimester, were available for just 49 pregnant mothers. Subjects were asked to fast overnight, and were transported in the morning to the Solís Clinic for phlebotomy. Venous blood was drawn using ethylene diamine tetraacetic acid (EDTA) as the anticoagulant, and samples were transported on ice to INNSZ in Mexico City within about four hours. Haematological analyses were performed using an electronic counter (model ZF, Coulter Electronics, Hialeah, FL). The INNSZ haematology laboratories provided controls that were analysed daily between samples, and duplicate samples were checked once per week. Plasma ferritin was assessed in duplicate with an

RIA (radio-immunoassay) kit (Ferrizyme, Abbott Laboratories, Berkeley, CA).

Social and other variables

Mexico NCRSP staff collected extensive socio-economic data, including information on household ownership of material goods and house construction. Earlier, a measure of household material wealth was constructed based on a principal components analysis of these data[30]. This variable has proved to be a good predictor of household and individual food intake ('dietary quality') in this population[30,31]. Other variables employed in this paper include self-reported level of maternal education, and the estimated energy needs of the household (based on the age, sex and weights of household members)[32].

Statistical analyses

All statistical analyses were conducted using SAS (SAS Institute, Cary, NC). Spearman correlations are employed in the dietary analyses because of skewed food and nutrient intake variables. All *P*-values are two-tailed. In the regression analyses, *pulque* intake per day was transformed (square root) to improve a skewed distribution. Interaction effects and curvilinear relationships were investigated using centred data; residual plots and influence statistics were used to assess the adequacy of the regression models[33].

PROC LOESS, which employs a locally weighted regression technique (loess), was also used to model the curvilinear *pulque* relationships[34]. Unlike classical regression, the loess technique does not require the researcher to specify a function (i.e. linear, quadratic, etc.) for use in modelling the data[35]. Loess curves were fitted using the direct method and iterative reweighting to improve robustness of fit and resistance to outliers.

Results

Of 70 women, 72.9% consumed *pulque* during pregnancy and 75.7% consumed the drink during the postpartum period. As would be expected, intakes of *pulque* during

the two time periods were highly correlated ($r = 0.67$, $P < 0.0001$, $N = 70$). Of 19 'non-consumers' during pregnancy, 52.6% reported *pulque* consumption later during the postpartum period. Of 17 postpartum 'non-consumers', 47.1% reported *pulque* consumption earlier during pregnancy.

For those mothers identified as *pulque* drinkers during pregnancy ($N = 51$), the beverage provided a median of 108 kcal (450 kJ) and 11.8 g ethanol day^{-1} (82 g week^{-1}). The latter quantity is roughly equivalent to daily consumption of a 12 oz bottle of 'light' beer. Intakes by some women were considerably higher, and nearly a third of pregnant women (28.6%) consumed more than 150 g ethanol week^{-1}, levels of intake that have been associated with increased risk of foetal alcohol effects (FAE)[15]. One pregnant woman reported drinking 81 g ethanol day^{-1} (570 g week^{-1}), which is equivalent to the alcohol in six 12 oz beers.

The median quantity of *pulque* consumed per drinking event was 0.5 litres (24 g of ethanol). Table 1 shows that half a litre of *pulque* provides an estimated 215 kcal, 23.5 g of ethanol, plus significant quantities of ascorbic acid, iron, thiamin and riboflavin. Infrequent drinkers, based on the percentage of days on which consumption was reported, tended to consume as much *pulque* per drinking event as more frequent drinkers ($r = 0.20$, $P = 0.1593$, $N = 51$). Therefore, even occasional drinkers may have had episodic intakes of potentially important amounts of alcohol.

The heaviest *pulque* drinkers, based on mean daily intake, consumed the beverage on a greater proportion of days ($r = 0.91$, $P < 0.0001$, $N = 51$), drank more per drinking event ($r = 0.51$, $P = 0.0001$, $N = 51$), and drank more than once during the day ($r = 0.68$, $P < 0.0001$, $N = 51$).

Pulque *consumption and maternal diets*

Diets during pregnancy were generally adequate in energy (2360 ± 610 kcal or 9.88 ± 2.55 MJ). As repeatedly observed in the industrialised countries, individuals who consumed greater quantities of alcohol showed no compensating decrease in energy from all other food

(pregnancy: $r = 0.04$, $P = 0.7151$; postpartum: $r = 0.02$, $P = 0.8548$)[1]. As a result, heavy *pulque* consumers had greater energy intakes (pregnancy: $r = 0.34$, $P = 0.0040$; postpartum: $r = 0.38$, $P = 0.0014$). The 10 heaviest drinkers during pregnancy consumed a median of 2847 kcal day^{-1} (11.91 MJ day^{-1}), or 786 kcal day^{-1} (3.29 MJ day^{-1}) more than the median energy intake for those 19 women who did not consume *pulque*.

Median intakes of eight micronutrients fell below two-thirds of the Mexican Recommended Dietary Intake (RDI) during pregnancy: vitamin B_6, thiamin, riboflavin, vitamin B_{12}, iron, ascorbic acid, vitamin E and vitamin A (Table 2)[36]. Biochemical assessments on Solís Valley women have demonstrated widespread deficiencies of iron and vitamin B_{12}[37,38]. Research on local children, which has examined a broader range of micronutrients, has demonstrated deficiencies of iron, riboflavin, vitamin B_{12}, vitamin A, vitamin E and zinc[39].

Pulque is a good source of four of the eight 'problem' micronutrients in Table 2. As would be expected, greater *pulque* consumption ($N = 70$) was associated with higher intakes of these four (ascorbic acid: $r = 0.76$, $P < 0.0001$; iron: $r = 0.43$, $P = 0.0002$; riboflavin: $r = 0.41$, $P = 0.0004$; thiamin: $r = 0.33$, $P = 0.0053$). Additionally, the alcohol and ascorbic acid in the beverage would be expected to increase the bioavailability of iron. Indeed, greater *pulque* intake during pregnancy, based on dietary recalls taken before a third trimester blood sample, was associated with higher plasma ferritin ($r = 0.34$, $P = 0.0148$, $N = 49$), but not with haemoglobin ($r = 0.07$, $P = 0.6332$, $N = 49$) or haematocrit ($r = 0.03$, $P = 0.8563$, $N = 49$).

Because *pulque* must be purchased or obtained by barter, variability in *pulque* intake might potentially influence intake of specific foods such as milk. However, no clear relationships were seen between *pulque* intake and consumption of other foods (not shown).

Control variables for the infant size and Bayley analyses

Multiple regression analyses (below) examine the relationships of maternal *pulque* consumption to infant size,

Table 2 Pregnant women's intakes of micronutrients in this population (*N*=70)

	% of RDI		Percentage of intake provided by *pulque*	
	Median	Q1–Q3*	Median	Q1–Q3*
Vitamin A	25.4	19.6–44.3	0.0	0.0–0.0
Vitamin E	35.0	28.0–47.9	NA†	NA†
Ascorbic acid	37.0	27.7–53.3	23.7	10.2–45.2
Thiamin	61.1	52.5–68.3	6.5	2.1–12.4
Riboflavin	46.8	35.6–60.3	6.2	2.9–15.6
Vitamin B_6	64.6	54.1–76.3	NA†	NA†
Vitamin B_{12}	46.1	31.0–93.2	NA†	NA†
Iron	62.6	54.9–74.9	10.7	4.7–19.7

* Q1 = first quartile (25th percentile), Q3 = third quartile (75th percentile).
† NA = not available. The quantity in *pulque*, if any, is unknown.

Table 3 Pearson correlations between potential confounders and the outcome and exposure variables ($N = 70$)

	Length at 1 month	Linear growth*	Mental	*Pulque*	Birth order	Mother's height	Mother's age	Mother's education	Household material wealth	Household energy needs
Length at 1 month	1.00	0.00	0.34	0.30†	−0.11	0.26	0.17	0.06	−0.07	−0.14
Linear growth		1.00	−0.08	0.03†	−0.01	0.41	−0.05	0.07	0.05	−0.12
Mental (raw) at 6 months			1.00	0.13	−0.09	−0.03	0.12	0.07	0.07	−0.01
Pulque				1.00	0.15	0.00	−0.04	0.06	0.16	0.05
Birth order					1.00	−0.08	−0.80	−0.22	−0.08	0.59
Mother's height						1.00	0.08	0.16	0.24	−0.15
Mother's age							1.00	0.33	0.04	−0.39
Mother's education								1.00	0.20	−0.07
Household material wealth									1.00	−0.16
Household energy needs										1.00

* Measured as residual length at 6 months controlling for length at 1 month.
† Square root of the *R*-square of the multiple regression containing linear and quadratic terms for *pulque* intake.

growth and Bayley performance. Table 3 shows the Pearson correlations among potential confounders and the outcome and exposure (*pulque*) variables. Interactions between *pulque* intake and several variables (including maternal size, infant sex, maternal education and household material wealth) were examined, and none were detected. Because of the small sample size, attempts were made to reduce the number of potential confounders included in the regression analyses (Table 4). In particular, birth order was included as a single variable that contained information on both maternal age and household energy needs. All regression models contain infant sex, maternal education, birth order and household material wealth as control variables. Additionally, the infant size models include the infant's age at measurement and maternal height. For the growth models, the time between measures and maternal height were added as control variables. For the Bayley analyses, age at Bayley administration was added to the regression models.

Pulque *intake and infant size at 0–8 days*
Mexico NCRSP infants tended to be small and to exhibit compromised postpartum growth. At 0–8 days, Solís infants were generally lighter and shorter than the WHO/

NCHS reference (length: 48.8 ± 1.80 cm, $N = 41$; weight: 3.24 ± 0.39 kg, $N = 56$; ponderal index: 2.79 ± 0.42, $N = 41$). Of 56 infants with weights at 0–8 days, two children (3.6%) had low 'birth weights' (<2.5 kg). Both infants were measured at 8 days postpartum and weighed 2.4 kg. Because the Mexico NCRSP did not assess gestational age, some children may have been born prematurely.

Maternal *pulque* intake during pregnancy suggested a curvilinear relationship with 0–8 days weight (not shown). However, a polynomial regression model was not statistically significant. Neither length nor the ponderal index at 0–8 days bore a clear relationship to *pulque* intake (not shown).

Pulque *intake and infant size at 1 month*
At 1 month ($N = 70$), Solís infants tended to be small-for-age and slightly heavy-for-length (length-for-age: $-0.99 \pm 0.81Z$; weight-for-age: $-0.22 \pm 0.68Z$; weight-for-length: $0.63 \pm 0.67Z$). Stunting was more prevalent (10.0% of infants) than 'underweight' (weight-for-age: $<-2Z$) (1.4%). No child had a weight-for-length below $-2Z$ ('wasted').

Figure 1 plots the relationship between length-for-age

Table 4 Multiple regression models predicting infant size at 1 and 6 months, Bayley mental and motor performance (raw scores), and growth between 1 and 6 months (residual) based on maternal intake of *pulque* during pregnancy*

		Intercept		Linear term		Quadratic term		
		B	SE	B	SE	B	SE	P-value
1 month ($N = 70$)	Length†	30.24177	7.79104	0.03106	0.03216	−0.01066	0.00382	0.0069
	Weight†	−0.16122	1.88707	0.00107	0.00779	−0.00180	0.00092	0.0567
6 months ($N = 69$)	Length†	22.13102	10.09092	0.03583	0.03812	−0.01053	0.00444	0.0207
	Weight†	−11.41685	4.56349	−0.01093	0.01724	−0.00178	0.00201	0.3782
	Mental‡	36.29157	14.11849	0.31550	0.15264	−0.03649	0.01738	0.0399
	Motor‡	12.13188	8.32753	0.08974	0.09003	−0.01683	0.01025	0.1058
1–6 months ($N = 69$)	Length§	−18.65802	5.61452	−0.01042	0.02389	0.00170	0.02389	0.5456
	Weight§	−8.75525	3.20850	−0.01588	0.01365	0.00124	0.00160	0.4414

B = parameter estimate; SE = standard error.
* *Pulque* consumption (kcal) was transformed by use of a square root, and then 'centred' (the mean subtracted) to avoid ill conditioning due to the quadratic term. Mean *pulque* intake was 78.5 kcal day^{-1}.
† Controlling for gender, age at anthropometry measurement, maternal height, birth order, maternal education and household material wealth.
‡ Controlling for gender, age at Bayley measurement, birth order, maternal education and household material wealth.
§ Controlling for gender, time between anthropometry measures, maternal height, birth order, maternal education and household material wealth.
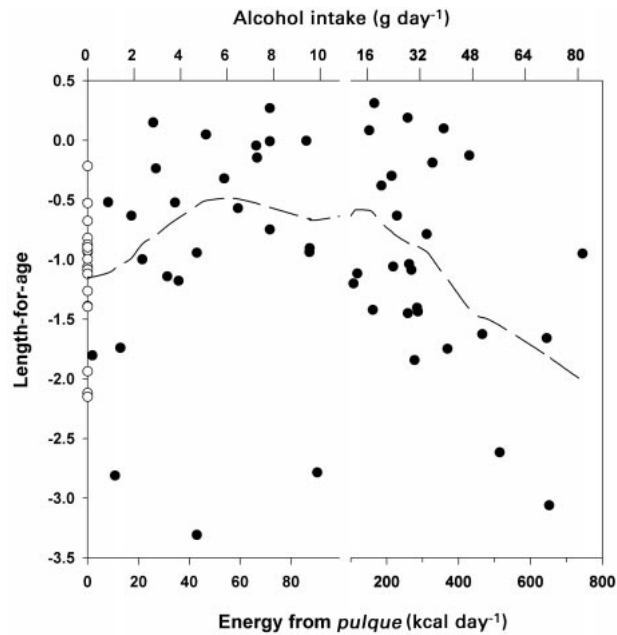
Fig. 1 Scatter plot ($N = 70$) showing the relationship of length-for-age Z-score at 1 month to average *pulque* intake during pregnancy. Scale is split to facilitate display of the relationships between length-for-age at 1 month and both very low and high *pulque* consumptions. 'Non-drinkers' are white circles. Curve was fitted using PROC LOESS

at 1 month and average consumption of *pulque* during pregnancy. *Pulque* intake exhibited a clear curvilinear relationship with length-for-age, although the relationship was less obvious for weight-for-age (not shown). In general, the smallest children were clustered at the extremes of *pulque* intake, while the largest infants had mothers who had consumed small-to-moderate quantities of *pulque*. The loess curve, a robust estimate of the relationship, suggests a decline in length-for-age with *pulque* intakes above 54 kcal day^{-1} (41 g ethanol week^{-1}).

Polynomial regression models, including a quadratic term for maternal *pulque* intake, were used to investigate these curvilinear relationships. Average *pulque* intake was transformed (square root) to improve normality and to better approximate the loess curves. Dependent variables were weight and length rather than Z-scores. Adjusted for the control variables, the curvilinear (quadratic) term was statistically significant for length (Table 4), but did not reach statistical significance for weight ($P = 0.0567$). Based on the regression equations, the highest predicted weights and lengths at 1 month were associated with *pulque* intakes of approximately 80–110 kcal day^{-1} or 61–84 g alcohol week^{-1}. Intakes above or below these were associated with declining size.

Pulque intake and infant size at 6 months and growth from birth to 6 months
Adjusted for the control variables, the associations

between maternal *pulque* intake and both length and weight at 6 months were weakened in comparison to 1 month, although length retained a statistically significant curvilinear relationship with *pulque* consumption (Table 4). Multiple regression models showed no relationship of *pulque* intake during pregnancy to length and weight growth between 1 and 6 months as measured by the 'residual method' (Table 4)[25].

Pulque and Bayley performance
The average age at the time of administration of Bayley Scales was 6.1 ± 0.5 months. Mean raw scores were 60.9 ± 6.7 on the mental scale, and 25.7 ± 5.1 on the motor scale. After adjusting for age using the Bayley norms, the average scores were 79.7 ± 14.6 on the MDI (mental) and 95.5 ± 18.3 on the PDI (motor) scales. Because these values fall below 100 (the Bayley 'norm'), these data indicate delays in development, particularly in mental development, as compared with US children. No significant gender differences were seen in either mental or motor performance.

Figure 2 shows the relationship between *pulque* intake in pregnancy and Bayley mental performance. As with infant length, low mental scores at 6 months were associated with very high intakes of *pulque*, while intakes of up to ~120 kcal day^{-1} (92 g ethanol week^{-1}) were associated with better scores. Because of minor variation in age, negative correlations between the 'normed' scores and age, and concerns about the validity of applying US norms to rural Mexican children, polynomial regression
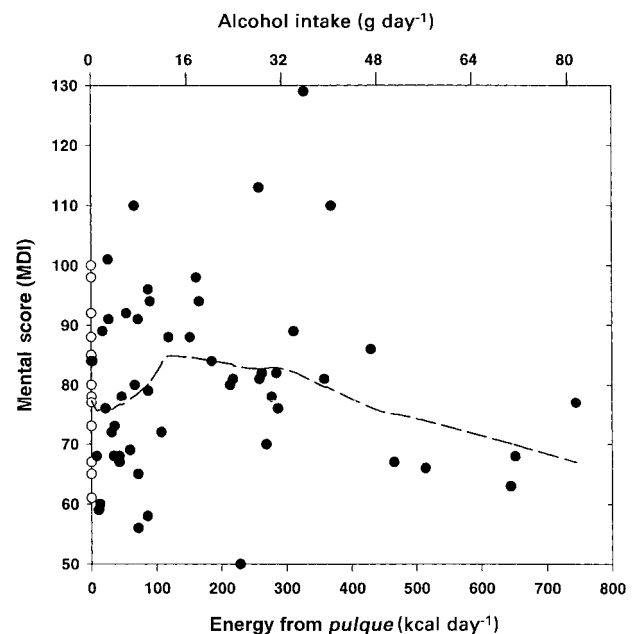

Fig. 2 Scatter plot ($N = 70$) showing the relationship between Bayley mental scores (MDI) at 6 months and average *pulque* intake during pregnancy. Curves were fitted using PROC LOESS. White circles indicate 'non-consumers'

analyses employed raw Bayley scores. Adjusting for the control variables, maternal *pulque* intake during pregnancy was associated with variation in infant mental performance, but not with motor performance (Table 4). One highly influential outlier, an extremely low mental score, was omitted from these analyses. Based on the regression equation, the highest predicted mental scores occurred with *pulque* intakes of 170–180 kcal day^{-1}, or 130–138 g ethanol week^{-1}.

An examination of Fig. 2 suggested that the decline in mental performance with higher pulque intake was largely due to four infants of heavy *pulque* drinkers. When infants of the heaviest drinkers (>450 kcal day^{-1} from *pulque*) were eliminated from the mental score analyses, the quadratic (non-linear) term lost statistical significance. Instead, higher *pulque* consumption during pregnancy (a main effect) was associated with higher mental scores at 6 months ($t = 2.35$, $P = 0.0222$, $N = 65$).

Discussion

More than 50 years ago, researchers in central Mexico emphasised the importance of *pulque* in rural diets, noting its consumption by both women and men[40,41]. In the mid-1980s, *pulque* remained a prominent component of Solís Valley diets; during the period of study, just six foods (*tortillas*, onions, sugar, vegetable oil, tomatoes and garlic) were consumed more frequently by valley households[21]. Anecdotal information suggests that the beverage continues to be an important part of contemporary diets in rural, central Mexico.

Laboratory analyses, although dated, show *pulque* can be a good source of ascorbic acid, riboflavin, iron and thiamin – all nutrients consumed in relatively low amounts by many Mexico NCRSP women. Therefore, even modest consumption of the traditional beverage has the potential to significantly increase intakes of key micronutrients, and to improve nutritional status. The potential significance of *pulque* as a micronutrient source is indicated by our unpublished research on the iron status of 125 non-pregnant Mexico NCRSP women. For these women, *pulque* was the leading dietary source of ascorbic acid, and the third leading source of iron (after *tortillas* and legumes). Moreover, greater *pulque* consumption during the 12 months prior to blood collection was predictive of higher iron stores, and decreased risk of a low haematocrit and haemoglobin.

Unfortunately, alcohol intakes during pregnancy, the result of *pulque* consumption, were often quite high among these women. By our calculations, nearly a third of infants were exposed to moderate-to-high average intakes of ethanol during gestation. Moreover, because the amount of *pulque* consumed per drinking event was only weakly related to the frequency of consumption, even occasional drinkers may have episodically exposed their foetus to potentially harmful amounts of alcohol.

Animal studies suggest that high peak blood alcohol levels are more likely to adversely effect foetal development than regular, low-level exposure[42].

Despite its likely public health significance, little has been published on the relationship of *pulque* intake to infant growth and development. In one of the few papers on the topic, Flores-Huerta *et al.* reported a high prevalence of low birth weight among 32 infants of Mexican mothers who consumed *pulque* during the prenatal period[43]. More recently, a cross-sectional study of 416 Solís Valley children found low weights-for-age (<$-2Z$) were associated with paternal intake of *pulque*, a variable that may well have been a proxy for prenatal exposure to alcohol[44].

The current paper, to the best of our knowledge, is the first to use longitudinal data to examine the relationship between maternal *pulque* intake during pregnancy and subsequent infant growth and development. Our analyses document curvilinear relationships between *pulque* intake and both child size and Bayley mental performance. Based on the polynomial regression models, intakes in excess of 61–84 g ethanol week^{-1} were associated with decreasing size at both 1 and 6 months; the inflection point was approximately 50% higher for Bayley mental scores (at approximately 130–138 g ethanol week^{-1}). Researchers have identified a broad range of thresholds above which maternal alcohol intakes have been associated with adverse effects in children[15]. And, our threshold values are broadly comparable with those reported in the literature[45–47]. However, our analyses also suggest a *beneficial* effect of low alcoholic beverage intake, which, if not due to confounding (including a generally better diet), may be attributable to the micronutrient content of *pulque*.

Although intriguing, a putative beneficial effect of low-to-moderate *pulque* consumption on child growth and development should be viewed with caution, particularly in view of the established dangers of alcohol and several limitations in study design. First, the sample size was relatively small, which limited our statistical ability to (1) detect subtle effects, (2) fully characterise complex curvilinear relationships, and (3) investigate potential interactions among the alcohol consumption, nutrient intake and household environment variables. Second, maternal *pulque* consumption was in all likelihood imperfectly measured, and occasional exposure to large amounts of alcohol (at religious festivals, weddings, etc.) very likely occurred and was missed. Lastly, the Mexico NCRSP was a prospective, cohort study, and interpretation should reflect the strengths and weaknesses of such an approach. In particular, a variety of unmeasured, or poorly measured, confounding variables may provide alternative explanations for the observed results. Nevertheless, our results are consistent with an adverse effect of maternal malnutrition during pregnancy on the subsequent size and development of the child. Additional

research will be needed to identify which nutrients, if any, are involved.

In conclusion, our data show intakes of alcohol by pregnant women were common in these six Solís Valley communities in 1985. Given current scientific knowledge of the adverse effects of ethanol on foetal development, public health interventions are needed to reduce heavy consumption of *pulque* during pregnancy, while increasing micronutrient intakes, in some areas of rural Mexico.

Acknowledgements

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