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Maternal Alcohol Use and Nutrition During Pregnancy: Diet and Anthropometry

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Abstract

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CONFLICT OF INTERESTS

The authors have no conflict of interests to disclose

Background: Despite known risks of prenatal nutritional deficiencies and studies documenting increased prevalence of poor dietary intake among nonpregnant alcohol abusers, the nutritional status of heavy drinking pregnant women remains largely unstudied. Animal models have found interactions between prenatal ethanol exposure and micronutrients, such as choline, folate, B12, and iron, and human studies have reported that lower maternal weight and body mass confer increased fetal alcohol-related risk.

Methods: One hundred and twenty-three heavy drinking Cape Coloured pregnant women and 83 abstaining controls were recruited at their first antenatal clinic visit. At 3 prenatal study visits, each gravida was interviewed about alcohol, smoking, and drug use and weight, height, and arm skinfolds were measured. Dietary intakes of energy, protein, fat, and major micronutrients were assessed from three 24-hour recall interviews.

Results: The majority of women gained less than the recommended 0.42 kg/wk during pregnancy. Whereas methamphetamine use was associated with smaller biceps skinfolds, an indicator of body fat, alcohol consumption was not related to any anthropometric indicator. Alcohol was related to higher intake of phosphorus, choline, and vitamins B12 and D. Alcohol, cigarette, and methamphetamine use were related to lower vitamin C intake. Insufficient intake was reported by >85% of women for 10 of 22 key nutrients, and >50% for an additional 3 nutrients.

Conclusions: Alcohol consumption during pregnancy was not associated with meaningful changes in diet or anthropometric measures in this population, suggesting that poor nutrition among drinkers does not confound the extensively reported effects of prenatal alcohol exposure on growth and neurobehavior. The poor gestational weight gain and high rates of insufficient intake for several nutrients in both the alcohol-exposed and control groups are also of public health importance.

Keywords

Nutrition; Alcohol Consumption During Pregnancy; Diet; Anthropometry; Fetal Alcohol Spectrum Disorders

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FETAL ALCOHOL SPECTRUM disorders (FASD) comprise a continuum of alcohol-related neurodevelopmental disorders ranging from the most severe, fetal alcohol syndrome (FAS), to nonsyndromal alcohol-related neurodevelopmental disorder, which is usually characterized by subtler neurobehavioral deficits than those seen with FAS (Hoyme et al., 2016). Worldwide, a significant number of women continue to drink heavily during pregnancy despite public health advisories and the availability of psychosocial interventions (ACOG, 2011; Warren et al., 2001). In the United States, prenatal alcohol exposure is the most common preventable cause of developmental disability, with an incidence of FAS of 1 to 3 children/1,000 live births and higher rates in endemic communities (e.g., some Native American populations; May et al., 2011, 2014a). In the Western Cape Province of South Africa, where rates of heavy drinking during pregnancy are endemically high among women from the Cape Coloured (mixed ancestry) community (Croxford and Viljoen, 1999), the prevalence of FAS is as high as 80 per 1,000 (May et al., 2014a).

Despite extensive evidence from animal research demonstrating important roles for prenatal nutrition in FASD, little is known about the nutritional status of heavy drinking pregnant women. Maternal nutritional status may confound or mediate the adverse effects of prenatal alcohol exposure on development if nutrition is poorer among heavy drinking women than among abstainers or low-level drinkers. Pregnant women commonly fail to consume recommended amounts of micronutrients, including several that may be especially important in FASD, such as choline, folate, vitamin B12, iron, and vitamin A (Muthayya et al., 2006; Zeisel, 2009). Heavy drinking pregnant women may be at even greater risk for micronutrient deficiencies, as alcoholics commonly choose alcohol over nutritious foods and are prone to underweight, hypoglycemia, and micronutrient deficiencies (Lieber, 1979). A study of nonpregnant alcohol abusers in the United Kingdom found that all participants had substandard intake of vitamin E and folate, and most had low intake of other nutrients as well (Manari et al., 2003). May and colleagues (2014b, 2016) conducted 2 cross-sectional case–control studies in rural areas of the Western Cape Province, South Africa, comparing the diets of mothers of children with FASD to mothers of children without FASD from the same school, using a single 24-hour recall interview. In the first of these studies, mothers of children with FASD reported lower dietary intake of calcium, riboflavin, and choline. In the second, however, mothers of children with FASD reported higher dietary intake for 13 of 25 nutrients examined and did not report lower intake for any nutrient. Neither study ascertained maternal diet during the index pregnancy, and both were limited by the use of a single recall interview, whereas 3 interviews are recommended to assess usual intake (Baranowski, 2013). In a recent randomized controlled trial of prenatal multivitamin and choline supplementation in the Ukraine, Coles and colleagues (2015) found that blood choline concentrations at recruitment among heavy drinking pregnant women were similar to those of controls. To our knowledge, no other published studies have prospectively examined the nutritional status of heavy drinking pregnant women.

Maternal nutrition may also act as an effect modifier, given the growing body of research in animal models demonstrating that maternal nutrition may alter fetal vulnerability to prenatal alcohol exposure. In one of the first experimental studies to address this issue, more severe skeletal ossification deficits were seen in alcohol-exposed rat pups whose mothers were fed a protein-deficient diet (Weinberg et al., 1990). Lower energy intake (e.g., calories) while drinking reduces the rate of ethanol (EtOH) metabolism, thereby leading to higher blood alcohol concentrations (BACs) and increased fetal exposure (Khaole, 2004; Ramchandani et al., 2001). Differences in body composition also affect alcohol metabolism, with smaller women attaining higher BACs than larger women for a given amount of intake (Lands, 1998). In cross-sectional studies, May and colleagues (2005, 2011, 2014b, 2016) found that mothers of school-aged children with FASD had smaller weight, height, head circumference, and body mass index (BMI) than mothers of children without FAS in the same community, but anthropometric measures were not obtained during pregnancy. In our Detroit prospective longitudinal cohort, we found that lower prepregnancy weight exacerbated the effects of alcohol on postnatal growth, suggesting greater vulnerability to the effects of prenatal alcohol exposure in children born to smaller mothers (Carter et al., 2013).

There is growing evidence that maternal intake of several micronutrients may also impact the vulnerability of the fetus to prenatal alcohol exposure. A recent randomized controlled

trial of prenatal multivitamin supplementation found that alcohol-exposed male infants whose mothers received multivitamins scored 5.6 points higher on the Bayley Mental Development Index than those whose mothers received placebo (Coles et al., 2015). Trials of supplementation with nutrients important in methyl donor metabolism, including folate, vitamin B12, and choline, have demonstrated protective effects in fetal alcohol animal models (Bekdash et al., 2013; Otero et al., 2012; Thomas et al., 2009; Xu et al., 2006, 2008), raising the possibility that deficiencies in these nutrients may a play critical role in alcohol-related epigenetic changes. Alcohol-related changes in vitamin A metabolism have also been shown to play an important role in the teratogenesis of alcohol in both supplementation and functional deficiency models, which may be due to interactions between EtOH and vitamin A metabolism by alcohol dehydrogenase (Kot-Leibovich and Fainsod, 2009; Kumar et al., 2010; Marrs et al., 2010; Satiroglu-Tufan and Tufan, 2004; Yelin et al., 2005). Prenatal alcohol exposure has been shown to disrupt infant iron homeostasis in humans and in a rat model (Carter et al., 2007; Miller et al., 1995), and iron deficiency has been shown to exacerbate the effects of alcohol on growth in humans and rats and neurobehavior in rats (Carter et al., 2007; Huebner et al., 2016; Rufer et al., 2012). Alcohol may also increase the risk of zinc deficiency (Flynn et al., 1981), which, in animal models, has been shown to exacerbate the teratogenic effects of alcohol (Keppen et al., 1990; Miller et al., 1983; Ruth and Goldsmith, 1981).

Despite the large body of evidence demonstrating important roles of nutrition in FASD, little is known about the nutritional status of heavy drinking pregnant women. We recently recruited a new prospective, longitudinal cohort of pregnant women in the Cape Coloured community in Cape Town, South Africa, a population in which we have previously documented effects of prenatal alcohol exposure on brain structure and function (De Guio et al., 2014; Diwadkar et al., 2013; Meintjes et al., 2010, 2014; Taylor et al., 2015), neurobehavior (Molteno et al., 2010, 2014), cognition (Jacobson et al., 2008, 2011; Lewis et al., 2015; Lindinger et al., 2016), placental development (Carter et al., 2016b), and growth (Carter et al., 2007, 2012). In this paper, we examine (i) the degree to which maternal nutritional status during pregnancy (indicated by both diet and anthropometry) is related to alcohol consumption during pregnancy and may, therefore, potentially play a confounding role in FASD; and (ii) the prevalence of inadequate nutritional intake in both heavy drinking pregnant women and controls. Given that confounding variables must be related to both exposure and developmental outcome (Jacobson and Jacobson, 2005), the degree to which alcohol-using pregnant women differ from controls in their nutritional intake may have important implications for evaluating the degree to which effects of prenatal alcohol exposure on development may be attributable to maternal nutritional status during pregnancy.

MATERIALS AND METHODS

Sample

Pregnant women were recruited from October 2011 to December 2015 from 2 antenatal midwife obstetric units that serve economically disadvantaged Cape Coloured communities in Cape Town. The Cape Coloured community is comprised of descendants of European,

Malaysian, Khoi-San, and black African ancestors, who historically worked on grape farms, where they were paid, in part, with wine. Each mother was interviewed at screening regarding her alcohol consumption both at time of conception and recruitment, using a timeline follow-back interview (Jacobson et al., 2002). The interview was adapted to reflect how pregnant women in this community drink, including information about type of beverage consumed, whether shared, and container size (using pictures of different containers, bottles, cans, glass size), for use in the calculation of standard drinks (Jacobson et al., 2008, 2017). Any woman averaging at least 1.0 oz absolute alcohol (AA)/d (1 oz AA≈ 2 standard drinks) or reporting binge drinking (≥2.0 oz AA/drinking occasion) was invited to participate in the study. Women initiating antenatal care who abstained or drank only minimally were invited to participate as controls. These 2 groups were recruited to enable us to focus on heavy drinkers, whose offspring are at greatest risk for FASD, and to examine them in relation to controls. Alcohol consumption was examined as a continuous variable, which has the advantage of assessing actual use across pregnancy, regardless of status at recruitment, and provides increased power to detect associations between alcohol consumption and developmental outcomes. A small group of methamphetamine ("tik") users from the same community who did not report heavy drinking at recruitment (n = 16) was also recruited as a comparison group. All women who reported drinking during pregnancy were advised to stop or reduce their intake, and women were referred for treatment, if they agreed. Exclusionary criteria included age <18 years, HIV infection, and pharmacologic treatment for medical conditions, including diabetes, hypertension, epilepsy, or cardiac problems. Informed consent was obtained from each mother. Consent and interviews were conducted in Afrikaans or English, depending on the mother's preference. Approval for human research was obtained from the ethics committees at Wayne State University, University of Cape Town (UCT) Faculty of Health Sciences, Columbia University Medical Center, and Boston Children's Hospital.

Ascertainment of Maternal Alcohol, Smoking, and Drug Use

In the initial timeline follow-back interview administered at recruitment, each woman was asked about her drinking on a day-by-day basis during a typical 2-week period around time of conception, with recall linked to specific times of daily activities. If her drinking had changed since conception, she was also asked about her drinking during the past 2 weeks and when her drinking had changed. Each mother was interviewed at 2 subsequent UCT visits, using the timeline follow-back interview and asked about her alcohol consumption during the previous 2 weeks. If there were any weeks since the recruitment visit when she drank greater quantities, she was asked to report her drinking for those weeks as well. Volume was recorded for each type of alcohol beverage consumed and converted to oz AA weights that reflect AA concentration in Cape Town (liquor—0.4, beer—0.05, wine—0.12, cider—0.06). Three summary measures were constructed by averaging across pregnancy: oz AA/d; oz AA per occasion, and frequency of drinking. We have previously validated this ascertainment protocol in relation to levels of fatty acid ethyl esters in meconium samples in this community (Bearer et al., 2003) and in relation to infant outcomes (Jacobson et al., 2002).

Anthropometric Measurements

Maternal height and head circumference were obtained using an upright, rigid stadiometer for height and a nondeformable plastic tape measure for head circumference. Weight (using a digital scale), BMI, mid-upper arm circumference (MUAC; using a nondeformable plastic tape measure), and biceps and triceps skinfolds (measures of body fat; using Lange calipers) were obtained at each prenatal visit using standard procedures (CDC, 2007). Each measurement was obtained twice by trained research staff blind to the women's alcohol and drug use (interexaminer reliability rs = 0.90 to 1.00). In cases of disagreement between the initial 2 measurements for height, weight, head circumference, and MUAC (defined as >0.5 kg for weight, >0.5 cm for height and head circumference, and >0.1 cm for MUAC), a third measurement was taken and the average of the 2 closest values was used for analyses. For biceps and triceps skinfolds, the average of the 2 measurements was used. Poor gestational weight gain was defined as <0.42 kg/wk (Rasmussen and Yaktine, 2009), and small MUAC was defined as <23 cm as an indicator of malnutrition during pregnancy (Kruger, 2005).

Dietary Assessments

At each prenatal study visit, a multiple-pass 24-hour dietary recall interview was administered (Baranowski, 2013) using pictures and portion size props in the Dietary Assessment and Education Kit (Chronic Diseases of Lifestyle Unit, Medical Research Council, Tygerberg, South Africa). The interviewer was either a registered dietician or a research assistant with extensive training in dietary interviewing by MS, then Head of the Division of Human Nutrition, UCT Faculty of Health Sciences. Dietary intake was quantified using FoodFinder®, a dietary analysis software program developed by the South African Medical Research Council (Tygerberg, South Africa), which utilizes the South Africa Foods Database with inclusion of nutrients added in grain fortification programs. Hand-written transcriptions were reviewed by a registered dietician/research scientist (LJB), who entered these data into the FoodFinder® software program. The 3 interviewers and LJB held regular Skype® meetings to discuss the interviews and any questions that arose and were blind regarding results of drug and alcohol interviews. As FoodFinder® does not give values for choline content, all reported foods were matched to a U.S. Department of Agriculture (USDA) food database food code (USDA et al., 2016) by MS and RCC, and choline content was calculated. Total dietary intake for each nutrient was calculated for each 24-hour period, and values from each interview were averaged to calculate average daily intake for each nutrient.

Average daily energy intake was considered inadequate if it was below the estimated energy requirement (EER) based on height, weight, and activity level (Henry, 2005) adapted for pregnancy based on Prentice and colleagues (1994). Based on vocation, all women were assigned low activity levels; none engaged in heavy labor (e.g., agriculture). Intake for a given nutrient was considered inadequate if a woman's estimated usual intake was below the Estimated Average Requirement (EAR) per the Dietary Reference Intake (Institute of Medicine, 2006; see Table S2) or, for fiber and choline, the Adequate Intake (AI), as no EAR has been determined. Nutrient adequacy ratios (NARs) were then calculated as the ratio of the average daily nutrient intake to the EER, EAR, or AI, with a maximum ratio value of 1.0. For these adequacy-related outcomes, given the potential for 24-hour

recall interviews to overestimate the prevalence of nutrient intakes at the upper and lower extremes, nutrient intake values were adjusted using the Institute of Medicine/Nutrition Research Council method, which transforms outcome distributions to more closely match those of the general population, while preserving cohort means (Dodd et al., 2006). As part of standard clinical care, pregnant women in this community are provided daily oral supplementation with 5 mg folic acid and 55.9 mg elemental iron (as 170 mg ferrous fumarate). Women were asked if they had received the supplements and how often they took them.

Because most women concentrated their drinking on Fridays and Saturdays and dietary interviews were held on weekdays, 24-hour recall data captured drinking days for only 19 women (15.0% of drinkers). Given the lack of prior studies on diet among heavy drinking pregnant women in this community, it was unclear if, on drinking days, women drink above and beyond their normal diet, alter the quality of their diet, or replace food with alcohol, as has been demonstrated in nonpregnant adults with alcohol abuse (Lieber, 1979; Manari et al., 2003). Given public health interest in *poor* dietary intake as a potential mediating factor in FASD, we estimated subjects' nutrient intakes in the worst of these 3 possibilities, in which women *replace food* with alcohol on drinking days while maintaining the same total daily caloric intake. In addition to the dietary intake outcomes described above, beverage-specific alcohol intake reported in timeline follow-back interviews (wine, liquor, cider, beer) for each woman was entered into FoodFinder®, and nutrient values from average daily alcohol intake were calculated. We then calculated the ratio of a woman's average daily calorie intake from alcohol to average daily calorie intake from all foods, and nutrient intake from nonalcohol foods was estimated by reducing all nutrient values by the proportion of calorie intake consumed from alcohol. For example, for a woman consuming 2500 kcal/d from 24-hour recall interviews and an average of 250 kcal/d from alcohol from timeline follow-back interviews, all 24-hour recall nutrient values were reduced by 10% to yield average daily nutrient intake from nonalcohol foods. Nutrient values from alcohol were then added to nutrient values from nonalcohol foods to create estimates of average daily nutrient intake from all foods, including drinking days.

Control Variables

Each woman was asked at both the antenatal and postnatal interviews how many cigarettes she smoked/d and how frequently (d/wk or month) she used illicit drugs, including cocaine, marijuana ("dagga"), methaqualone ("mandrax"), and methamphetamine ("tik") during pregnancy. To examine the validity of the maternal reports of drug use, urine samples were collected from the last 105 women enrolled. Samples were tested by our research nurse using the AccuTest™ 6 + 2 drugs of abuse panel test (DTA Pty Ltd, Cape Town, South Africa), an immunochemical assay that detects metabolites of drugs commonly used in this community (amphetamines, cocaine, methaqualone, methamphetamine, opiates, and marijuana [THC]), as well as pH and creatinine to test for sample adulteration. No woman refused urine drug testing. Maternal gravidity, education, and socioeconomic status (Hollingshead, 2011) were assessed during prenatal interviews. The USDA Core Food Security Module Questionnaire, a detailed questionnaire that assesses household food

security during the preceding 12 months, was administered prenatally (National Research Council, 2006).

Statistical Analyses

Statistical analyses were performed using SAS v.9.3 software (SAS Institute Inc., Cary, NC). All variables were examined for normality of distribution and, where positively skewed (>3.0), subjected to log transformation. Intraclass correlations and within-subject coefficients of variation (Hankinson et al., 1995) for dietary nutrient intakes were calculated using the method developed by Hertzmark and Spiegelman (https://cdn1.sph.harvard.edu/wp-content/uploads/sites/271/2012/09/icc9.pdf). Anthropometric measures were regressed on alcohol consumption, drug use, and control variables, using linear regression models for gestational weight gain and mixed models with repeated measures for all other anthropometric outcomes. To examine the relation between alcohol consumption and energy or a given nutrient, mixed regression models with repeated measures were performed, adjusting for energy intake for all outcomes except for energy intake (Willett, 2013a). Linear regression models were performed to examine the relation between alcohol consumption and drug use to the NAR for a given nutrient. To control for potential confounders, all models were re-run, adjusting for any predictors related to a given outcome at $p < 0.10$.

RESULTS

Sample Characteristics and Alcohol and Drug Use

The majority of the mothers (89.8%) were 20 to 40 years of age, with drinkers 2 years older than controls on average (Table 1). Three-fourths (76.1%) had attended but only 12.2% had completed high school; drinkers had attended school almost 1 year less than controls. Maternal age, parity, and gravidity were highly collinear ($rs = 0.73$ to 0.94, $ps < 0.0001$). Because gravidity and parity were related to fewer outcomes than age, only maternal age was included as a potential confounder in multivariable models. More than half of the study participants reported low food security, with 46.2% of drinkers reporting very low food security compared with 26.6% of controls. Most women received prenatal iron/folic acid supplementation (87.2%) and reported good adherence, taking the supplement on most days (93.5% among those supplemented); 72.5% had fullterm pregnancies; 94.7% of women completed at least two 24-hour recall interviews; and 64.6% completed 3 interviews. Heavy drinkers and controls did not differ in number of visits (2.6 vs. 2.5, respectively, $t(204) = -1.60$, $p = 0.110$).

As expected, alcohol use was heavy among drinkers, who averaged 9.4 standard drinks per occasion on 2.4 days per week around time of conception and 8.4 standard drinks on 1.3 d/wk across pregnancy. As we have previously reported (e.g., Carter et al., 2016b), drinkers concentrated their alcohol use on the weekends, and binge drinking was common, with 89.8% of drinkers averaging at least 4 standard drinks per occasion. Drinkers were more likely to smoke cigarettes than controls but reported a similar number of cigarettes/d. Although cigarette smoking was common, number of cigarettes smoked per day was generally light, with 82.2% of smokers reporting <0.5 pack/d, and only 3.1% reporting >1.0 pack (20 cigarettes/d). Marijuana use was also more common among drinkers than controls.

Average daily alcohol consumption was negatively correlated with methamphetamine use ($r = -0.16$, $p < 0.05$). Of the 16 women recruited as methamphetamine users, 3 reported drinking alcohol during pregnancy. An additional 11 women recruited as alcohol users later reported methamphetamine use.

Results of the urine drug tests were consistent with maternal reports of marijuana, methamphetamine, cocaine, and opiates for 97 (92.4%) of those tested. Only 2 of 99 (2.0%) women denying methamphetamine use tested positive for this substance, and 5 of 89 (3.6%) women denying marijuana tested positive for THC. Among 8 women testing positive for methamphetamine, 6 also tested positive for methaqualone despite denying using it. An additional 2 women denying all drug use also tested positive for methaqualone. In this community, methaqualone is commonly mixed with methamphetamine or marijuana prior to being sold, often without the user's knowledge. The barbiturate-like qualities of methaqualone counteract some of the activating negative side effects of methamphetamine, such as anxiety, jitteriness, and racing thoughts. Consistent with maternal reports, no urine tests were positive for cocaine or opiates.

Maternal Anthropometry

As expected, weight and BMI increased across pregnancy in both groups (Table 1). Less than half of women had adequate gestational weight gain. Small MUAC was rare (10.2% had low values on at least 1 visit). Drinkers had shorter stature than controls by 2.1 cm. Average head circumference was similar between groups. Alcohol consumption was not related to maternal weight, gestational weight gain, BMI, triceps or biceps skinfolds, or MUAC (Table 2). Similarly, cigarette smoking and marijuana use were not associated with any anthropometric outcomes. Methamphetamine use was associated with smaller biceps skinfolds, a measure of body fat ($p < 0.05$), and associations with smaller weight and BMI fell just short of statistical significance ($p < 0.10$). Maternal age was positively associated with weight, BMI, and MUAC, as expected, and negatively associated with gestational weight gain. Maternal education was positively associated with weight, BMI, triceps skinfolds, and MUAC, and socioeconomic status was positively associated with weight.

Dietary Intake

Intraclass correlations and within-subject coefficients of variation for dietary nutrient intakes were similar to those of NHANES and other peer-reviewed epidemiologic studies in the United States (Table S1; Willett, 2013b). On average, women reported 2,286.4 kcal/d dietary energy intake (SD = 692.2 kcal/d); EER averaged 2,058.4 kcal/d. As expected, energy intake was positively related to gestational weight gain ($r = 0.22$, $p < 0.01$). Alcohol consumption was not related to energy intake or intake of carbohydrates, protein, or fat (Table 3). Average daily alcohol consumption and drinks per occasion were weakly related to higher intake of phosphorus, which is found in beer. Among the methyl donor-related micronutrients, average daily alcohol consumption and drinking frequency were weakly associated with higher dietary choline intake, while drinks per occasion was weakly associated with higher vitamin B12 intake. When nutrient intakes were estimated assuming that women substituted alcohol for their normal diet on the days when they drank, the relation of prenatal alcohol

exposure to dietary intakes was virtually unchanged (Table 4). Maternal cigarette smoking was weakly associated with lower copper intake (Table 3). Methamphetamine use was associated with lower intake of carbohydrates, higher intake of chloride, and lower intake of vitamin C. Among control variables, maternal age was associated with lower phosphorous intake, while years of education were associated with higher intake of copper and vitamin C.

For 10 of 22 nutrients examined (fiber, calcium, copper, iodine, iron, zinc, choline, folate, vitamin C, and vitamin D), more than 85% of women in this cohort reported inadequate intake (Table 5), and for an additional 3 nutrients (magnesium, selenium, and thiamin), more than half reported inadequate intake. For vitamin C, drinking frequency was associated with a lower NAR (ratio of reported intake to AI). Drinks per occasion was associated with a higher NAR for vitamin D. When examining estimated NARs including days on which women drank (Table 6), with alcohol nutrient content estimated from timeline follow-back interviews, average daily alcohol consumption and drinking frequency were associated with lower vitamin C intake from nonalcohol foods and from all foods, including alcohol. Cigarette smoking was moderately associated with lower NARs for folate and vitamin C. Methamphetamine use was moderately associated with a lower NAR for vitamin C. Alcohol consumption, cigarette smoking, and methamphetamine use were not associated with whether a woman took prenatal iron/folic acid supplements regularly (yes/no), whereas days per month marijuana use was related to a decrease in taking the supplements regularly ($\beta = -0.28$, $p < 0.001$).

DISCUSSION

In this prospective cohort study of pregnant women recruited at initiation of prenatal care, alcohol consumption was not associated with alterations in maternal weight, BMI, gestational weight gain, MUAC, or arm skinfolds and was associated with dietary intake of only a few nutrients. To our knowledge, this is the first study to prospectively examine the diet and anthropometry of heavy drinking pregnant women. In order for a maternal nutritional variable to play a confounding role in the association between prenatal alcohol exposure and FASD outcomes, the variable must be associated with both exposure and outcome (Jacobson and Jacobson, 2005). Our findings of a lack of association between alcohol consumption and poor nutrition across virtually all of the nutritional indicators thus support the inference that the teratogenic effects of alcohol we and others have demonstrated in this community are specific to alcohol and not attributable to poorer diet or anthropometric measures among drinkers.

Use of methamphetamine, a strong appetite suppressant, was associated with smaller biceps skinfold thickness, a measure of body fat, and associations with lower BMI and weight fell just short of statistical significance, consistent with a case–control study in China that found lower BMI among subjects with methamphetamine addiction (Lv et al., 2016). By contrast, our finding that alcohol consumption was not associated with alterations in weight, gestational weight gain, or indicators of body fat, such as BMI and skinfolds, suggests that heavy drinkers generally maintained the same daily dietary energy intake (e.g., kilocalories/d) on drinking days as on nondrinking days, thus *replacing* nonalcohol foods with alcohol. Otherwise, the dietary energy contribution from alcohol (201.5 kilocalories/d

among drinkers) would have led to a positive energy balance and greater weight and BMI among drinkers. This finding is consistent with prior reports of nonpregnant alcohol-abusing adults, who commonly choose alcohol over more nutrient-dense foods (Lieber, 1979; Manari et al., 2003). Of note, drinkers had shorter stature but similar head circumference as compared with controls. It should be noted that height and head circumference are fixed by adulthood and influenced by genetics, childhood nutrition, and the mother's own prenatal exposures, which may include alcohol in this community where alcohol consumption during pregnancy across multiple generations in the same family is thought to be common (May and Gossage, 2011). These anthropometric parameters would therefore not be expected to be related to nutrition or alcohol intake during the current pregnancy, by contrast to those which reflect recent nutrition (e.g., BMI, skinfolds, weight gain, MUAC), which could be related to nutrition or alcohol intake during the pregnancy.

Alcohol consumption was associated with very few dietary indicators. When examining average daily intake calculated from 24-hour recalls, drinking was associated with higher intake of phosphorus, which is nutrient-dense in beer, choline, and vitamins B12 and D, and with a lower ratio of a subject's average daily intake to the EAR for vitamin C. Of note, these findings were virtually unchanged when we estimated average daily intake including drinking days with nutrient intake from alcohol consumption reported in timeline follow-back interviews replacing nonalcohol foods. Cigarette smoking and methamphetamine use were associated with lower vitamin C intake; methamphetamine use was also associated with lower carbohydrate intake. No associations between marijuana use and diet were seen. Although p-values for several associations between alcohol and drug use and diet were <0.05, the regression coefficients for all but vitamin C were quite small ($\beta \leq 0.20$), indicating that these relations are unlikely to be clinically meaningful. Our findings are generally consistent with May and colleagues' (2014b, 2016) 2 Western Cape cross-sectional case–control studies comparing mothers of school-aged children with FASD to mothers of children without FASD from the same community, 5 to 7 years after the index pregnancy, in that there were few differences in dietary intake between groups and a large proportion of both groups reported inadequate nutrient intake. In the more recent of May and colleagues' (2014b, 2016) 2 studies, mothers of children with FASD had higher intake of 13 nutrients, including phosphorus, choline, and vitamins B12 and D, which were also positively associated with alcohol consumption in our study. Women in our urban Cape Town prospective cohort reported higher energy intake and were somewhat less likely to report inadequate intake than women in May and colleagues' (2016) rural cohort, presumably reflecting differences between study settings in socioeconomic status and/or resource availability. Of note, studies of nonpregnant alcohol-abusing adults have demonstrated important effects of alcohol absorption and utilization of nutrients (e.g., B-complex vitamins, iron; Lieber, 1979). Thus, although the dietary intake of heavy drinkers did not differ greatly from controls, drinkers may still be at risk for physiologic nutrient deficiencies due to problems with absorption and utilization of the nutrients. Future studies including comprehensive nutrient biochemical profiles are needed.

Although few associations between alcohol consumption during pregnancy and diet were seen, inadequate intake was seen in both groups for over half of the nutrients examined, despite the fact that wheat flour, bread, and maize meal in South Africa are fortified with

vitamin A, thiamin, riboflavin, niacin, pyridoxine, folate, iron, and zinc. This pattern of nutrient inadequacies is likely attributable to less frequent intake of legumes, whole grains, green leafy vegetables, dairy and possibly liver, with the low fiber intake probably also reflecting low intakes of legumes and whole grains, while the relatively higher levels of adequacy for vitamin B12, niacin, and vitamin B6 may be explained by intake of meats lower in iron content, such as chicken. Inadequate intake of many of the nutrients seen in this cohort may pose developmental risks independent of alcohol exposure. Furthermore, animal models suggest that deficiencies in methyl metabolism-related nutrients (choline, folate, vitamin B12), antioxidants (vitamins A, C, and E), or the heavy metals iron and zinc may exacerbate the teratogenic effects of alcohol. Of these nutrients, over 85% of women in this cohort reported inadequate intake of choline, folate, vitamin C, iron, and zinc. Most women (81.5%) reported taking iron/folic acid supplements regularly as part of antenatal care. While these supplements are high dose (5 mg folic acid, 55.9 mg elemental iron) and should result in adequate daily intake, it should be noted that most women initiated antenatal care late into the second trimester and thus had inadequate intake of iron and folic acid for much of the pregnancy. Over half of the women had poor gestational weight gain, which is a risk factor for intrauterine growth retardation independent of alcohol consumption (Neggers et al., 1995). Smaller weight and BMI lead to increased BAC for a given amount of alcohol intake, and poor weight gain may thus lead to increased alcohol exposure to the fetus (Khaole, 2004). Studies are needed to determine the potential impact of poor gestational weight gain, which, like lower prepregnancy weight, may exacerbate the teratogenic effects of alcohol.

Alcohol, cigarette smoking, and methamphetamine use during pregnancy were independently associated with lower vitamin C intake, which plays a critical role as an antioxidant. None of the mothers in this study exhibited scurvy, the disease state manifest in vitamin C deficiency, but subclinical vitamin C deficiency cannot be ruled out. Cigarette smokers have higher dietary vitamin C requirements due to oxidative stress and alterations in vitamin C metabolism (Institute of Medicine, 2006). Oxidative stress has been implicated as a potential mechanism in the teratogenic effects of FASD (Hill et al., 2014; Wentzel et al., 2006) and may thus be worsened in the setting of low vitamin C intake. Thus, the associations seen between alcohol consumption and smoking with lower dietary vitamin C may warrant dietary interventions among drinkers and smokers, particularly as the tolerable upper limit for vitamin C for pregnant women (1,800 to 2,000 mg/d) far exceeds average daily intake in this cohort (M = 70.9 mg/d; Institute of Medicine, 2006).

These data, to our knowledge, provide the first evidence for the validity of 24-hour recall interviews among heavy drinking pregnant women in the Cape Coloured community. The FoodFinder® database is not comprehensive for copper, iodine, selenium, lutein, beta carotene, and vitamin D, and is thus likely to underestimate dietary intakes for these nutrients. However, such error would be expected to be random and therefore similar between drinkers and controls. Furthermore, the specificity of FoodFinder® to the South African population is an important strength, given large differences in the diets and available prepared foods between South Africa and the United States. Last, as women were assessed in trimesters 2 and 3, the current study did not assess potential effects of alcohol use on maternal anthropometry or diet in the prepregnancy period or the first trimester.

As recall interviews were administered on weekdays, the current study did not assess diet on drinking days for most women. Little is known about how heavy drinking pregnant women alter their diet on drinking days in this community. In a study of nonpregnant adolescents (ages 12 to 16) with a pattern of frequent binge drinking in Cape Town, female subjects with alcohol use disorders had higher daily energy intake than nondrinking controls, suggesting that they drank above and beyond their normal dietary intake (Naude et al., 2011). Our finding that alcohol consumption was not associated with higher maternal weight, BMI, or gestational weight gain provides support for the inference that adult pregnant women in this community substitute alcohol calories for food. When we examined estimates of nutrient intakes based on the assumption that the study participants replaced food with alcohol on the days when they drank, the relation of prenatal alcohol exposure to nutrient levels was virtually unchanged, suggesting that our findings were not biased by our inability to interview the mothers during the weekend. Nonetheless, potential alterations in diet quality (e.g., which foods women choose to eat) on drinking days were not directly examined in the current study.

This study has limitations common to other longitudinal studies of nutrition and anthropometry. Noise surrounding estimates of maternal alcohol consumption may obscure some associations, but differences between true and estimated exposure are likely small, given the validity of the interviewing techniques, which has been demonstrated in this community in relation to meconium levels of fatty acid ethyl ester metabolites of alcohol (Bearer et al., 2003), infant and child behavior (Jacobson et al., 2002, 2008; Lindinger et al., 2016), somatic growth (Carter et al., 2016a), and brain structure (De Guio et al., 2014; Fan et al., 2016; Meintjes et al., 2014) and function (Woods et al., 2015). Twenty-four hour dietary recall interviews can yield inaccurate estimates of usual intake due to sources of random error (e.g., inaccurate recall of items and/or portion sizes) and systematic error (e.g., effects of alcohol use on subjects' ability to accurately recall their diets). Nevertheless, the regression models in the current study yielded multiple small-magnitude coefficients, significant at $p < 0.05$, suggesting that power was sufficient to detect true associations in our data. Moreover, the fact that intraclass correlations and within-subject coefficients of variation for dietary nutrient intakes were similar to those of NHANES and other peer-reviewed epidemiologic studies in the United States, indicates that random error in this study did not exceed levels generally accepted in the nutritional epidemiology community.

Our finding that energy intake predicted gestational weight gain further supports the validity of the 24-hour recall data. Women were asked what their prepregnancy weight was, but almost all reported not knowing. As data regarding subjects' prepregnancy BMI were not available, we used the cutoff for recommended gestational weight gain for women with normal prepregnancy BMI (Rasmussen and Yaktine, 2009). Overweight and obesity are uncommon in this impoverished community; low prepregnancy BMI is more common. As the cutoff for adequate gestational weight gain for women with low prepregnancy BMI is higher (0.51 kg/wk) than that for women with normal BMI, the true prevalence of poor gestational weight gain in this population may be higher than we have reported.

CONCLUSIONS

In this prospective cohort study of heavy drinking pregnant women and controls, we found no clinically significant associations between alcohol consumption and diet or anthropometric measures. Given that confounding factors must be related to both exposure and outcome, these data support the inference that the adverse effects of prenatal alcohol exposure seen in this community are not attributable to poorer maternal nutritional status among heavy drinkers. Dietary intake of energy and the large majority of nutrients assessed, including choline, folate, vitamin C, iron, and zinc, were inadequate in both the alcohol-consuming and control women, and gestational weight gain was inadequate in more than half of both groups. In light of the evidence from laboratory animal studies, we can hypothesize that these nutritional inadequacies may exacerbate the teratogenic effects of alcohol in this population and contribute to the unusually high rates of FASD. Additional studies examining the degree to which inadequate nutrition exacerbates the growth and neurobehavioral impairment seen in FASD are, therefore, warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Sample Characteristics

	Controls					Heavy drinkers					
	N	***M***	**SD**	***n***	**%**	***N***	***M***	**SD**	***n***	**%**	***p*** [a]
Maternal age at conception (year)	83	25.5	4.8			123	27.7	5.7			0.004
Parity (no.)	83	1.4	1.2			123	1.7	1.5			0.105
Gravidity (no.)	83	2.5	1.3			123	2.9	1.7			0.109
Marital status (no. married)	83			34	41.0	123			34	27.6	0.046
Education (years school completed)	83	10.0	1.6			123	9.3	1.7			0.005
Socioeconomic status[b]											
Food security[c]	79					196					0.017
High food security				37	46.8				32	27.4	
Marginal food security				10	12.7				12	10.3	
Low food security				11	13.9				19	16.2	
Very low food security				21	26.6				54	46.2	
Received prenatal iron/folic acid supplementation	80			69	86.3	119			104	87.4	0.814
Takes supplements most days (supplemented only)				65	93.2				104	90.4	0.367
Weeks gestation											
Initiation of antenatal care	83	18.7	6.0			123	17.3	5.9			0.111
Visit 1	83	25.5	5.0			123	22.9	5.8			0.001
Visit 2	78	29.9	5.0			116	27.0	5.6			<0.001
Visit 3	46	34.0	3.9			78	32.5	4.0			0.050
Delivery	83	39.0	2.2			123	38.8	2.1			0.626
Height (cm)	81	159.0	5.5			119	156.9	6.5			0.016
Weight (kg)											
Visit 1	80	65.5	13.9			120	61.4	12.1			0.145
Visit 2	76	66.8	13.2			115	63.1	13.0			
Visit 3	47	67.9	10.1			77	65.0	14.0			
Gestational weight gain (kg/wk)	76	0.4	0.3			116	0.4	0.3			0.600
< 0.42 kg/wk				37	48.7				64	55.2	0.379

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	Controls					Heavy drinkers					
	N	***M***	**SD**	***n***	**%**	***N***	***M***	**SD**	***n***	**%**	***p*** [a]
BMI											
Visit 1	80	26.0	5.5			119	224.9	4.9			0.530
Visit 2	76	26.4	5.2			114	25.6	4.9			
Visit 3	47	26.9	3.8			77	26.4	4.9			
Triceps skinfold (mm)											
Visit 1	81	16.9	6.1			120	15.6	5.1			0.195
Visit 2	76	16.6	6.0			114	16.5	5.6			
Visit 3	47	16.2	5.2			77	15.4	5.1			
Biceps skinfold (mm)											
Visit 1	81	9.2	4.0			120	7.9	4.0			0.104
Visit 2	76	9.2	3.8			114	8.3	4.6			
Visit 3	47	8.6	3.3			77	8.2	3.5			
Mid-upper arm circumference (MUAC; cm)											
Visit 1	81	28.8	4.1			120	27.7	4.0			0.142
Visit 2	76	28.7	4.0			115	27.8	4.1			
Visit 3	47	28.9	3.4			77	28.1	4.1			
Head circumference (cm)	81	53.9	1.9			119	53.5	1.7			0.067
Alcohol and drug use											
AA/d (oz)	83	0.0	0.0			123	0.9	1.2			<0.001
AA/drinking day (oz)	83	0.2	0.5			123	4.2	2.4			<0.001
Drinking days/wk (days)	83	0.0	0.1			123	1.3	1.1			<0.001
No. of reporting cigarette smoking	83			57	68.7	123			106	86.2	0.002
Cigarettes/d (smokers only)		6.1	5.9				6.8	4.1			0.435
No. of reporting marijuana use	83			8	9.6	123			29	23.6	0.011
Marijuana use (users only; days/month)		4.0	4.7				9.7	9.4			0.026
No. of reporting methamphetamine use	83			15	18.1	123			12	9.8	0.083
Methamphetamine use (users only; days/month)		8.8	8.0				4.5	5.4			0.119

AA = absolute alcohol; 1 oz AA ≈ 2 standard drinks.

[a]From χ^2 for categorical variables and *t*-tests for all continuous variables except for weight, BMI, and MUAC, for which values from analysis of variance (ANOVA) models, with control for weeks gestation at time of measurement, are presented.

[b] Hollingshead (2011) Four Factor Index of Social Status Scale.

[c] From USDA food security interview (National Research Council, 2006).

Table 2.

Relation of Maternal Alcohol Consumption, Drug Use, and Control Variables to Anthropometric Measures

Anthropometric indicator	Average daily alcohol consumption	Average alcohol consumption per drinking occasion	Drinking frequency	Cigarette smoking	Marijuana use	Methamphetamine use	Age	Education	SES[a]
Weight[b]	−0.02	0.02	−0.03	−0.08	0.02	−0.12†	0.19**	0.19**	0.16*
Gestational weight gain[c]	−0.03	0.05	0.07	−0.09	−0.03	0.00	−0.19**	0.03	0.12
BMI[b]	0.01	0.04	0.01	−0.11	0.01	−0.14†	0.17*	0.17*	0.08
Triceps skinfold[d]	0.03	−0.01	0.07	−0.05	−0.10	−0.10	0.09	0.15*	0.02
Biceps skinfold[d]	0.01	0.00	0.04	−0.08	−0.07	−0.13*	0.03	0.11†	0.09
Mid-upper arm circumference[b]	−0.04	0.02	−0.04	−0.07	−0.04	−0.10	0.20**	0.19**	0.13†

[a] SES = socioeconomic status as measured on the Hollingshead (2011) Four Factor Index of Social Status Scale.

[b] Values are regression coefficients for the given outcome from mixed models with repeated measures, adjusting for weeks gestation at time of measurement.

[c] Values are regression coefficients for the given outcome from univariate linear models.

[d] Values are regression coefficients for the given outcome from univariate mixed models with repeated measures.

† $p < 0.10$

* $p < 0.05$

** $p < 0.01$.

Table 3.

Relation of Alcohol Consumption, Drug Use, and Control Variables to Average Daily Intake of Nutrients Calculated from 24-Hour Recall Interviews

	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency		Cigarette smoking		Marijuana use		Methamphetamine use		Age		Education		SES[a]	
	β^1	β^2	β^1	β^2	β^1	β_2	β^1	β^2	β^1	β_2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2
Macronutrients																		
Energy	−0.02		0.04		−0.04		−0.07		−0.08		−0.05		0.02		0.07		0.00	
Carbohydrates	−0.03		−0.03		−0.03		0.00		−0.02		−0.05 *	−0.05 *	0.00		0.04 †	0.03	0.03 †	0.02
Protein	0.04		0.04		0.03		−0.04		0.00		0.01		−0.05		0.00		0.02	
Fat	−0.01		0.02		−0.02		0.00		0.02		0.03		0.01		−0.03		0.00	
Polyunsaturated																		
Fat	0.02		0.07		0.00		−0.02		0.04		0.03		−0.01		−0.01		0.04	
Trans fat	−0.06		−0.07 †		−0.05		0.02		−0.03		0.00		0.02		0.02		0.03	
Cholesterol	0.04		0.04		0.03		−0.01		−0.04		−0.02		−0.03		0.03		0.02	
Fiber	0.00		0.00		−0.02		−0.04		−0.01		−0.06 †	−0.07 †	−0.06 †	−0.07 †	−0.01		0.01	
Minerals																		
Calcium	−0.02		0.04		−0.06		−0.01		−0.02		−0.04		−0.04		0.00		0.04	
Chloride	0.00		0.01		−0.01		0.03		0.01		0.15 ***		0.05		0.00		−0.04	
Copper[b]	−0.02		0.01		−0.03		−0.07 *	−0.07 *	−0.01		−0.04		−0.05		0.06 †		0.08 *	0.08 **
Fluoride	0.04		0.04		0.01		0.01		−0.06		−0.01		0.03		0.06		0.02	
Lodine	0.02		0.03		0.02		−0.01		−0.04		−0.01		−0.01		−0.03		−0.02	
Iron	0.01		0.04		−0.02		−0.04		−0.03		−0.01		0.03		−0.04		0.01	
Magnesium	0.04		0.03		0.04		−0.04		−0.02		−0.01		−0.02		−0.01		−0.01	
Phosphorus	0.05 †	0.07 *	0.06 *	0.08 **	0.04		−0.04		−0.01		−0.02		−0.06 *	−0.08 **	−0.01		0.01	
Potassium	0.00		0.03		0.01		−0.04		−0.03		−0.02		−0.02		−0.01		−0.03	
Selenium	0.03		0.02		0.02		−0.01		−0.03		−0.05		0.04		0.04		0.00	
Sodium	0.01		0.00		0.01		0.00		0.02		0.05		0.03		−0.02		−0.03	
Zinc	0.03		0.04		0.03		−0.03		−0.01		−0.01		−0.04		−0.01		−0.01	

	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency		Cigarette smoking		Marijuana use		Methamphetamine use		Age		Education		SES[a]	
	β^1	β^2	β^1	β^2	β^1	β_2	β^1	β^2	β^1	β_2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2
Methyl donor-related nutrients																		
Choline	0.09 *		0.05		0.09 *		−0.02		−0.04		0.00		−0.03		0.03		−0.01	
Folate[b]	−0.03		0.00		−0.04		−0.06		−0.03		−0.05		0.00		0.04		0.03	
Lutein[b]	−0.01		−0.01		0.00		0.00		−0.02		−0.03		0.03		−0.06		0.02	
Methionine	0.04		0.04		0.03		−0.02		0.01		0.00		−0.05		0.03		0.04	
Vitamin B12[b]	0.03		0.12 **		0.01		−0.02		0.00		0.01		−0.04		0.03		0.05	
B-complex vitamins																		
Niacin	0.05		0.05		0.05		−0.03		−0.02		−0.02		−0.05		−0.01		−0.03	
Riboflavin	0.00		−0.04		0.01		−0.04		−0.07 †		0.00		0.02		0.03		−0.01	
Thiamin	−0.02		0.01		−0.04		0.00		−0.02		0.01		−0.01		0.01		0.00	
Vitamin B6	0.00		0.01		0.00		−0.01		−0.02		0.01		0.06 †		0.01		0.00	
Antioxidants																		
Beta carotene[b]	−0.05		−0.04		−0.03		−0.04		0.02		0.03		0.08 †		−0.04		0.00	
Vitamin A[b]	−0.06		−0.04		−0.08 †		−0.07		0.01		−0.01		0.06		0.02		0.05	
Vitamin C[b]	−0.05		−0.01		−0.06		−0.07		−0.06		−0.13 **		−0.13 **		−0.02		0.05		0.11 *	0.10 *
Vitamin E	−0.01		0.04		−0.02		0.04		0.03		0.00		0.00		0.05		0.03	
Other																		
Vitamin D	0.07 †		0.10 *		0.04		0.04		0.04		0.01		−0.02		−0.01		0.00	
Vitamin K[b]	0.00		0.02		−0.01		−0.05		−0.02		−0.01		0.05		−0.02		0.01	

β^1 = standardized regression coefficient for the given nutrient from mixed models with repeated measures adjusting for energy intake, except for the outcome energy intake.

β^2 = standardized regression coefficient for the given nutrient from mixed models with repeated measures adjusting for energy intake (except for the outcome energy intake) and all predictors for which univariate β at $p < 0.10$.

[a]SES = socioeconomic status as measured on the Hollingshead (2011) Four Factor Index of Social Status Scale.

[b] Nutrient values logged due to skewness >3.0.

† $p < 0.10$

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$.

Table 4.

Relation of Alcohol Consumption to Average Daily Intake of Nutrients Estimated for the Scenario in Which Women Replaced Food with Alcohol on Drinking Days

	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency	
	β^1	β^2	β^1	β^2	β^1	β^2
Macronutrients						
Energy	−0.03		0.02		−0.05	
Carbohydrates[a]	−0.04		−0.05†		−0.05*	−0.03
Protein	0.03		0.02		0.03	
Fat	−0.05		−0.01		−0.05	
Polyunsaturated fat	0.00		0.07		−0.02	
Trans fat	−0.10		−0.12†		−0.10	
Cholesterol	0.04		0.05		0.03	
Fiber	−0.03		−0.03		−0.05	
Minerals						
Calcium	−0.03		0.05		−0.08	
Chloride	−0.03		0.00		−0.03	
Copper[b]	−0.02		0.02		−0.05	
Fluoride	0.02		0.05		−0.01	
Iodine	0.00		0.02		0.01	
Iron	−0.01		0.03		−0.05	
Magnesium	0.01		0.03		−0.01	
Phosphorus[c]	0.07*	0.10**	0.08*	0.11**	0.06†	0.05
Potassium	0.00		0.04		−0.02	
Selenium	0.00		0.02		0.00	
Sodium	−0.01		−0.03		0.00	
Zinc	0.02		0.01		0.03	
Methyl donor-related nutrients						
Choline	0.13**		0.09†		0.13**	
Folate[b]	−0.05		0.00		−0.06	
Lutein[b]	−0.02		−0.02		0.00	
Methionine	0.03		0.02		0.03	
Vitamin B12[b]	0.10		0.16*		0.02	
B-complex vitamins						
Niacin	0.07		0.07		0.06	
Riboflavin	−0.01		−0.05		0.00	
Thiamin	−0.06		−0.03		−0.07	
Vitamin B6	−0.02		0.01		−0.01	
Antioxidants						

	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency	
	β^1	β^2	β^1	β^2	β^1	β^2
Beta carotene[b]	−0.07		−0.08		−0.03	
Vitamin A[b]	−0.10†		−0.07		−0.09	
Vitamin C[b]	−0.04		0.02		−0.07	
Vitamin E	−0.04		0.04		−0.04	
Other						
Vitamin D	0.07		0.11†		0.04	
Vitamin K[b]	−0.02		−0.04		−0.06	

β^1 = standardized regression coefficient for the given nutrient from mixed models with repeated measures adjusting for energy intake, except for the outcome energy intake.

β^2 = standardized regression coefficient for the given nutrient from mixed models with repeated measures adjusting for energy intake (except for the outcome energy intake) and all predictors for which univariate β at $p < 0.10$.

[a] β^2 models included the given alcohol variable, education, Hollingshead (2011) socioeconomic status and methamphetamine use.

[b] Nutrient values logged due to skewness >3.0.

[c] β^2 models included the given alcohol variable and age.

† $p < 0.10$

* $p < 0.05$

** $p < 0.01$.

Table 5.

Prevalence of Inadequate Intake[a] and Relation of Alcohol and Drug Use to Nutrient Adequacy Ratios[b] Calculated from 24-Hour Recall Interviews

	Average daily intake *M*(SD)	Inadequate intake n (%)	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency		Cigarette smoking		Marijuana use		Methamphetamine use	
			β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2
Macronutrients														
Energy (kcal/d)	2295.0 (825.0)	86 (41.7)	0.00		0.01		0.00		0.01		0.01		0.01	
Carbohydrates (g/d)	275.4 (97.4)	3 (1.44)	0.06		−0.03		0.06		−0.02		0.03		0.02	
Protein (g/d)	70.8 (26.5)	49 (24.4)	0.00		0.01		0.00		0.02		0.06		0.02	
Fiber[c] (g/d)	17.2 (7.5)	197 (95.6)	−0.02		0.04		−0.05		−0.14*	−0.12†	−0.07		−0.13†	−0.12†
Minerals														
Calcium (g/d)	471.1 (272.8)	188 (92.6)	−0.04		0.09		−0.10		−0.05		−0.08		−0.09	
Copper (mg/d)	1.2 (0.6)	204 (100.0)	−0.03		0.05		−0.06		−0.10		−0.08		−0.07	
Iodine (μg/d)	40.9 (24.2)	206 (100.0)	0.00		0.08		−0.01		−0.06		−0.12†		−0.05	
Iron (mg/d)	12.0 (4.4)	203 (99.5)	0.02		0.12†		−0.06		−0.12†		−0.12†		−0.06	
Magnesium (mg/d)	257.4 (100.0)	145 (71.1)	−0.01		0.12†		−0.06		−0.12†		−0.06		−0.03	
Phosphorus (mg/d)	1008.6 (394.2)	13 (6.4)	0.07		0.06		0.07		−0.02		−0.01		0.01	
Selenium (μg/d)	52.7 (26.9)	108 (52.4)	0.05		0.08		0.03		−0.06		−0.02		0.06	
Zinc (mg/d)	10.2 (4.1)	204 (100.0)	0.03		0.09		0.01		−0.10		−0.08		−0.06	
Methyl donor-related nutrients														
Choline (mg/d)	315.5 (176.6)	182 (88.4)	0.06		0.12†		0.02		−0.07		−0.11		−0.01	
Folate (μg/d)	245.4 (156.2)	203 (98.5)	−0.06		0.03		−0.10		−0.15*		−0.10		−0.11	
Vitamin B12 (μg/d)	5.7 (12.7)	0 (0.0)												
B-complex vitamins														
Niacin (mg/d)	23.4 (8.8)	11 (5.3)	−0.05		0.02		−0.06		−0.08		0.01		0.04	
Riboflavin (mg/d)	2.2 (1.8)	16 (7.8)	0.00		−0.01		−0.02		−0.02		0.03		0.02	
Thiamin (mg/d)	1.1 (0.4)	126 (61.2)	0.00		0.11		−0.06		−0.11		−0.08		−0.01	

	Average daily intake *M*(SD)	Inadequate intake n (%)	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency		Cigarette smoking		Marijuana use		Methamphetamine use	
			β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2
Vitamin B6 (mg/d)	3.1 (1.2)	3 (1.5)	0.04		0.05		0.03		−0.03		0.04		0.03	
Antioxidants														
Vitamin A (μg/d)	781.5 (1220.7)	0 (0.0)												
Vitamin C[d] (mg/d)	70.9 (77.6)	174 (85.3)	−0.12†	−0.10	−0.07		−0.16*	−0.15**	−0.27***	−0.22***	−0.13†	−0.06	−0.23***	−0.21**
Vitamin E (mg/d)	13.1 (6.5)	91 (44.2)	−0.04		0.08		−0.06		−0.06		−0.02		−0.01	
Other														
Vitamin D (μg/d)	4.3 (3.7)	202 (98.1)	0.11		0.18**		0.05		0.04		0.03		0.00	

β^1 = values are standardized regression coefficients for the given nutrient from univariate linear models.

β^2 = values are standardized regression coefficients for the given nutrient from multivariable linear models adjusting for all predictors for which univariate β at $p < 0.10$.

[a]Defined as average daily nutrient intake (adjusted using the Nutrition Research Council [NRC] method; Dodd et al., 2006) below the estimated energy requirement (Henry, 2005; Prentice et al., 1996) for energy or, for nutrients, the Estimated Average Requirement (EAR) or, where no EAR is available, the Adequate Intake (AI) (Institute of Medicine, 2006).

[b]Defined as the ratio of the average daily nutrient intake (adjusted using the NRC method) to the EAR or, where no EAR is available, the AI, with a maximum ratio value of 1.0 (REF).

[c]β^2 models included the given alcohol variable, age, cigarette smoking, and methamphetamine use.

[d]β^2 models included the given alcohol variable, Hollingshead (2011) socioeconomic status, cigarette smoking, marijuana use, and methamphetamine use.

†$p < 0.10$

*$p < 0.05$

**$p < 0.01$

***$p < 0.001$.

Table 6.

Relation of Alcohol Consumption to Estimated Nutrient Adequacy Ratios[a] from Nonalcohol Foods and All Foods, Estimated for the Scenario in Which Women Replaced Food with Alcohol on Drinking Days

	Nonalcohol foods						All foods					
	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency		Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency	
	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2
Macronutrients												
Carbohydrates	−0.03		0.01		−0.06		−0.03		0.01		−0.06	
Protein	−0.06		−0.02		−0.09		−0.06		−0.02		−0.09	
Fiber[b]	−0.07		0.03		−0.13†		−0.06		−0.05		−0.11	
Minerals												
Calcium	0.03				−0.13†		−0.06		0.05		−0.11	
Copper	−0.09		−0.04		−0.12†	−0.09	−0.06		0.00		−0.10	
Iodine	−0.03		0.03		−0.04		−0.03		0.03		−0.04	
Iron	−0.05		0.03		−0.11		−0.04		0.04		−0.10	
Magnesium	0.06		0.04		0.06		−0.02		0.09		−0.06	
Phosphorus	−0.01		0.00		−0.04		0.06		0.04		0.06	
Selenium	0.00		0.00		−0.02		0.00		0.00		−0.02	
Zinc	−0.02		0.02		−0.03		−0.02		0.02		−0.03	
Methyl donor-related nutrients												
Choline	0.03		0.05		0.00		0.06		0.10		0.03	
Folate	−0.10		−0.03		−0.13†		0.06		0.02		−0.09	
B-complex vitamins												
Niacin	−0.04		−0.03		−0.06		−0.05		−0.04		−0.06	
Riboflavin	−0.02		−0.02		−0.05		−0.03		−0.03		−0.06	
Thiamin	−0.04		0.03		−0.09		−0.04		0.03		−0.10	
Vitamin B6	0.00		0.00		−0.02		0.00		0.00		−0.03	
Antioxidants												

	Nonalcohol foods						All foods					
	Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency		Average daily alcohol consumption		Average alcohol consumption per drinking occasion		Drinking frequency	
	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2	β^1	β^2
Beta carotene												
Vitamin A	0.01		0.00		−0.02		0.01		0.00		−0.02	
Vitamin C[c]	−0.14*	−0.15*	−0.10		−0.18**	−0.20**	−0.14*	−0.15*	−0.10		−0.18**	−0.20**
Vitamin E	−0.07		0.01		−0.09		−0.07		0.01		−0.09	
Other												
Vitamin D	0.06		0.12†		0.02		0.06		0.12†		0.02	

β^1 = values are standardized regression coefficients for the given nutrient from univariate linear models.

β^2 = values are standardized regression coefficients for the given nutrient from multivariable linear models adjusting for all predictors for which univariate β at $p < 0.10$.

[a]Defined as average daily nutrient intake (adjusted using the Nutrition Research Council [NRC] method; Dodd et al., 2006) below the estimated energy requirement (Henry, 2005; Prentice et al., 1996) for energy or, for nutrients, the Estimated Average Requirement (EAR) or, where no EAR is available, the Adequate Intake (AI) (Institute of Medicine, 2006).

[b]β^2 models included the given alcohol variable, Hollingshead (2011) socioeconomic status and cigarette smoking.

[c]β^2 models included the given alcohol variable, Hollingshead (2011) socioeconomic status, cigarette smoking, marijuana use, and methamphetamine use.

†$p < 0.10$

*$p < 0.05$

**$p < 0.01$.