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Food insecurity is a risk factor for metabolic dysfunction-associated steatotic liver disease in Latinx children

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Summary

Introduction: Metabolic dysfunction-associated steatotic liver disease (MASLD) is the most common chronic liver disease among US children. Studies have associated food insecurity with MASLD in adults, but there are few studies of pediatric MASLD, particularly in high-risk populations. We assessed the impact of household food insecurity at 4 years of age on MASLD in Latinx children.

Methods: Using a prospective cohort design, Latina mothers were recruited during pregnancy and followed with their children until early to mid-childhood. Our primary exposure was household food insecurity at 4 years of age measured using the validated US Household Food Security Food Module. Our primary outcome, MASLD, was defined as alanine transaminase (ALT) ≥95th% for age/gender plus body mass index (BMI) ≥85% at time of ALT measurement (assessed between ages 5–12). We used multivariable logistic regression models to test for independent associations between household food insecurity and pediatric MASLD.

Results: Among 136 children, 28.7% reported household food insecurity at 4 years of age and 27.2% had MASLD in early to middle childhood. Approximately 49% of children with MASLD and 21% of children without MASLD were food insecure ($p < 0.01$). Exposure to household food

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AUTHOR CONTRIBUTIONS

Sarah L. Maxwell, Janet M. Wojcicki, Jennifer C. Price, Philip Rosenthal and Emily R. Perito all collaborated to conceive the study design. Janet M. Wojcicki developed the cohorts and collected the data. Sarah L. Maxwell, Janet M. Wojcicki and Jennifer C. Price analysed the data. All authors were involved in writing the paper and had final approval of the submitted and published versions.

CONFLICT OF INTEREST STATEMENT

No conflict of interest was declared.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

insecurity at age 4 was independently associated with a 3.7-fold higher odds of MASLD later in childhood (95% CI: 1.5–9.0, $p < 0.01$).

Conclusions: Exposure to household food insecurity at 4 years of age was associated with increased risk for MASLD later in childhood. Further studies are needed to explore mechanism(s) and impact of reducing food insecurity on risk for MASLD.

Keywords

food insecurity; health disparities; MASLD; metabolic health; steatotic liver disease

1 | INTRODUCTION

Metabolic dysfunction-associated steatotic liver disease (MASLD)[1] is the most common chronic liver disease in children in the United States.[2–5] MASLD describes a spectrum of steatotic liver disease associated with at least one known cardiometabolic risk factor,[1] from hepatic steatosis to steatohepatitis, which can progress to liver fibrosis, cirrhosis and end-stage liver disease.[1,6,7] In children and adolescents, prevalence of MASLD increases with obesity, Latinx ethnicity (especially those of Mexican and Central American origins), male sex and older age.[2,5,8,9] There is a paucity of longitudinal studies, especially in these high-risk groups, on risk factors associated with the development of pediatric MASLD.[9,10] While genetic, metabolic and dietary risk factors have been identified, the range and interplay of factors placing Latinx children at the highest risk of developing MASLD remain unclear.[8,11] Thus, there is an urgent need to clarify these complex relationships to decrease MASLD-related health disparities among Latinx children.

Several recent studies among adults in the United States found that household food insecurity was independently associated with MASLD and advanced liver fibrosis.[12,13] Household food insecurity is defined as households that at times were unable to acquire adequate food for one or more household members because the household had insufficient income and other resources for food.[14] One recent study highlighted an interaction between food security and obesity: adults with obesity and very low food security had increased risk of MASLD compared to adults with obesity and food security.[13] In another study, adults with MASLD and food insecurity had poor diet quality, which was significantly associated with fibrosis.[15] Adults with food insecurity may have higher rates of obesity due to a worse diet quality and lower access to medical care, which leads to a high burden of cardiometabolic disease and increased risk for liver disease.[12] Two recent studies examining food insecurity among children receiving care for MASLD at liver clinics in the Midwest found that food insecurity is not uncommon[16] and is associated with future health-related unmet social needs.[17]

No previous studies, to our knowledge, have examined the association of early exposure to household food insecurity on childhood MASLD. This is particularly important for Latinx families as Latinx children have high rates of both household food insecurity[14] and MASLD. Our primary aim in this study was to evaluate the association between household food insecurity in early childhood (at 4 years of age) and MASLD in early to mid-childhood in two combined longitudinal birth cohorts of Latinx children of primarily Mexican and

Central American origins. We hypothesized that children with early exposure to household food insecurity were at increased risk for MASLD compared to those that were food secure.

2 | METHODS

2.1 | Study design and study subjects

We included data from two prospective longitudinal birth cohorts of Latinx children whose mothers were recruited in pregnancy and were primarily of Mexican and Central American origins ($n = 298$). These cohorts were designed to explore early life risk factors for the development of pediatric obesity and associated metabolic diseases.[18,19] Children were born at the University of California, San Francisco, or the Zuckerberg San Francisco General Hospital during two time periods, 2006–2007 (Hispanic Eating and Nutrition [HEN] cohort) and 2011–2013 (Latino, Eating, and Diabetes [LEAD] cohort). Children and their mothers have been followed up annually from birth until 2021 as described in more detail below.

At the time of enrollment, Latina mothers expecting a healthy newborn with a non-high-risk pregnancy were recruited in prenatal clinics to both the HEN and LEAD cohorts, which used similar inclusion and exclusion criteria except with regard to type 2 diabetes mellitus and gestational diabetes. The HEN cohort excluded insulin-dependent diabetic mothers; the LEAD cohort did not. The detailed recruitment protocol and study methods have been described previously.[18–20] In summary, both cohorts included mothers that spoke English or Spanish, denied illicit drug or alcohol use, polycystic ovarian syndrome or self-reported eating disorders. If newborns had any contraindications to breastfeeding or had an Apgar score <7 at 5 min of life, the mother and infant pairs were excluded.

Written consent was provided annually by all mothers for themselves and their children. The study was approved by the Committee on Human Research (CHR), the Institutional Review Board (IRB) of the University of California, San Francisco.

2.2 | Cohort baseline, follow-up visits and study measurements

Mothers in both cohorts had prenatal visits. Children and mothers in both cohorts had visits at birth, 6 months, 1 year and then annually thereafter. Specifics of the study visits and measurements collected at the study timepoints are described below.

Maternal and family sociodemographic data including maternal ethnicity (Mexican, Central American or other Hispanic), language use (Spanish, Spanish/English or only English) and participation in the Special Supplemental Food Program for Women, Infants and Children (WIC) was collected at baseline during the prenatal visit. Maternal self-reported history of hypertension (HTN) including gestational hypertension, diabetes mellitus including gestational diabetes (GDM) and pre-pregnancy body mass index (BMI; kg/m^2) were also collected at baseline and verified by the study staff by confirming with the patient's medical record. Infant gestational age, sex and birthweight were extracted from the medical record at birth.

2.3 | Anthropometrics and blood pressure

At each annual follow-up visit, child anthropometric measures were obtained, including: length/height, weight and waist circumference. Blood pressure measurements were assessed annually with an automatic oscillometer Omron HBP-1300 (Omron Healthcare, IL, USA), using the mean of three measurements. Child overweight was defined as BMI percentile ≥85.0% and ≤95.0% for age and sex, and child obesity was defined as BMI percentile ≥95.0% for age and sex using Centers for Disease Control (CDC) 2000 growth charts.[21,22] A BMI *Z*-score of 1 is 1 standard deviation from the mean for age, height and sex. We classified BMI *Z*-scores of −0.99 to 0.99 as normal weight, 1 to 1.99 as overweight and ≥2 as obesity.[23]

2.4 | Diet

Annual dietary assessments of children were conducted beginning at 2 years of age. Intake of sugar-sweetened beverages (SSBs) and fast food were assessed annually in children 2 to 5 years of age using validated food frequency questionnaires that were developed for use in Mexican children and validated in Latinx children.[24,25] SSBs included intake of fruit juice (<100%), fruit drinks, soda, Kool-Aid or sweetened tea/coffee. Fast food was defined as any McDonalds, Burger King, Wendy's, KFC or other popular ready-to-go foods. We categorized high SSB intake as >2× a week and high fast food intake as >1× a week at 5 years of age based on our previous studies.[20,26]

2.5 | Household food security

For the main exposure: household food security over the past 12 months was assessed when the child was 4 years of age in both cohorts, using the 18 question US Household Food Security Food Module (US HFSSM), a validated scale by USDA.[14,27] Other timepoints were collected in both cohorts, but 4 years of age is the earliest measurement in both cohorts. Household food security was categorized using the four standard USDA classifications: (1) high (raw score zero), (2) marginal (raw score 1–2), (3) low (raw score 3–7) (4) and very low (raw score 8–18).[27] High household food security, as defined by the USDA, describes households that have no problems or anxiety about reliably accessing adequate food[14,27]; marginal is defined as problems/anxiety occasionally concerning accessing adequate food, but the quality/variety, and/or quantity of food is not reduced. Low is defined as reduced quality, variety and desirability of food intake, but the quantity of food intake has not been substantially altered; and very low implies that eating patterns of one or more household members were disrupted and food intake was reduced because the household lacked money and other resources for food. The USDA classifies households with high and marginal food security as food secure and those with low and very low food security as food insecure.[14,27]

2.6 | MASLD sub-study

We screened children for MASLD when children in the LEAD cohort were 5–8 years of age and children in the HEN cohort were 8–14 years of age. Of the original 298 mother–child pairs, 137 children (46%) had serum cardiometabolic laboratory tests conducted to screen for MASLD.

Children were assessed for metabolic health, including liver transaminases (alanine aminotransferase [ALT] and aspartate aminotransaminase [AST]), glucose and lipids, including: haemoglobin A1c (HgbA1c), insulin, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL) and uric acid. We used the AAP Obesity Guidelines/ NHLBI Criteria for Lipid Testing Results to determine normal and abnormal values for cardiometabolic labs.[28,29]

For the main outcome: children were categorized as MASLD if they had a BMI (kg/m^2) ≥85% for their age and sex and an ALT ≥95th % for age and sex (cut-point for males ≥25.8 IU/L cut-point for females ≥22.1 IU/L), based on US norms.[22,30] These ALT cut-points have sensitivities and specificities for detecting MASLD of 80% and 79% respectively for boys and 92% and 85% respectively for girls.[30]

3 | STATISTICAL ANALYSES

Our primary exposure was household food insecurity and our primary outcome was MASLD. We used descriptive statistical analyses to estimate the proportion of children with exposure to household food insecurity and those with MASLD. We assessed the frequency of covariates including maternal and child demographics and health characteristics in our cohort.[31–37] All data were presented as percentages and medians with interquartile ranges (IQRs). We checked all continuous covariates for normality using the Shapiro–Wilk test.

We subsequently assessed the association between our main predictor, food security status and these demographic, maternal and child health parameters. In our analysis, those with food security included those who had a high food security or marginal food security score on the USDA questionnaire and food insecurity included those with a low or very low food security score based on USDA definitions.[14] For covariates with normal distributions, we used a Student's *t*-test to test for differences between groups, and for covariates with non-normal distributions we used two sample Wilcoxon rank sum (Mann–Whitney) tests. For dichotomous or categorical variables, we used chi-squared or Fisher's exact tests.

We subsequently assessed MASLD in relation to child and family demographics and maternal and child health metrics using a similar approach. As our two cohorts had different mean ages at the time that MASLD was assessed, we also stratified by age using a cut-point of 10 years, which separated the cohorts to assess for differences by age or cohort in relation to MASLD.

To test for the potential biases from missing data as our MASLD cohort only represented a subset of the total initial HEN and LEAD cohorts, we assessed if there were any sociodemographic differences including participation in WIC, ethnicity and language use among those who received metabolic labs and those who did not (137/289 or 46%). There were no statistically significant differences in language use, WIC participation or maternal ethnicity between those with metabolic labs and those without. Additionally, we assessed sociodemographic differences among the cohorts for missing data for food security assessment when the child was 4 years old (122/136 or 89.7%). There were similarly no statistically significant differences in maternal age, WIC participation or ethnicity among mothers who completed food security screening when the children were 4 years of age and those who did not. However, mothers who did complete food security screening were more likely to only speak Spanish compared with those that did not.

3.1 | Multivariable logistic regression

We used multivariable logistic regression models to assess if exposure to household food insecurity versus food security when the child was 4 years old was an independent predictor of MASLD in early to middle childhood. Variables significant at $p < 0.05$ in bivariate analyses were included in multivariable analyses. The child's age category (<10 or ≥10 years) at the time of MASLD evaluation and sex were included in all multivariable models. We used STATA 17.0 (StataCorp) for all analyses.

4 | RESULTS

4.1 | Participant characteristics

We included 136 Latinx mother/child pairs of which 59.9% of mothers were of Mexican origins and 35.7% were of Central American origins; 91.2% of mothers reported speaking Spanish as a primary language (Table 1). Although income status was not directly assessed, 94.1% of families were enrolled in WIC during pregnancy. Our primary exposure: household food insecurity when the child was 4 years of age was reported in 28.7% of households. Nearly half of the children were male (47%). The median age at MASLD assessment was 11.2 years (IQR: 7.0–11.5); 68.4% of children were ≥10 years of age, and 57.3% had overweight/obesity (Table 1).

When we stratified our sample by cohort or by <10 years of age at the time of MASLD assessment versus ≥10 years of age, the two groups had some demographic and metabolic differences. The older group of children had younger mothers, lower birthweight *Z*-scores, lower AST levels and higher triglyceride, insulin levels and waist circumferences compared to the younger group of children. The younger group consumed more fast food at 5 years of age than the older cohort at the same age (Supplemental Table 1).

4.2 | Factors associated with household food insecurity

Sociodemographic and health-related characteristics that were associated with exposure to household food insecurity when the child was 4 years of age included: Central American ethnicity (vs. Mexican) ($p = 0.03$), lower gestational age ($p < 0.01$), lower birthweight *Z*-scores ($p < 0.03$), higher BMI-*Z* scores at 2 years of age ($p = 0.03$) and greater consumption of fast food when the child was 5 years of age ($p = 0.02$) compared with children in food secure households (Table 2). Household food insecurity at 4 years of age was not significantly associated with overweight or obesity alone (using closest BMI measurements to the time of the laboratory metabolic measurements) compared to those who were in food secure households ($p = 0.78$).

4.3 | Factors associated with MASLD

The overall prevalence of MASLD was 27.2% (Table 3); 56.8% of children with MASLD were male ($p = 0.17$). Of the children with MASLD, 24.3% were <10 years of age and

75.7% were ≥10 years of age ($p = 0.26$). Children with MASLD had higher median BMI *Z*-scores at 2 years of age compared to children without MASLD ($p < 0.01$) with 54.0% having overweight/obesity (BMI *Z*-score ≥1) ($p = 0.03$). Children with and without MASLD did not differ by SSB intake or fast-food consumption at 5 years of age (Table 3).

Children with MASLD also had abnormal values of other components of metabolic syndrome, including: lower HDLs; higher fasting insulin levels; higher fasting triglycerides; larger waist circumferences; and higher systolic and diastolic blood pressure measurements than children without MASLD ($p < 0.01$ for all variables, Table 3). At the time of laboratory assessment, children with MASLD had median BMI *Z*-scores more than double than those without MASLD ($p < 0.01$) with children with MASLD having median BMI-*Z* scores of 2.1 (IQR 1.6–2.3), which is classified as obesity compared to median BMI *Z*-scores of 0.9 (IQR 0.2–1.6) in children without MASLD, which is classified as normal weight (Table 3).

5 | ASSOCIATION OF HOUSEHOLD FOOD INSECURITY AND MASLD

Children with MASLD were more than twice as likely to live in food insecure households when the child was 4 years of age compared to those without MASLD: 48.6% of the MASLD group reported household food insecurity compared to 20.7% in the non-MASLD group ($p < 0.01$) (Table 3; Figure 1).

In multivariable analysis adjusting for age (<10 or ≥10 years), sex and BMI *Z*-score at 2 years of age, household food insecurity at 4 years of age was associated with an almost fourfold increased odds of MASLD in later childhood: OR 3.7 (95% CI: 1.5–9.0, $p < 0.01$) compared with children living in food secure homes (Table 4). Higher BMI *Z*-scores at 2 years of age were also independently associated with MASLD (OR of 1.6; 95% CI: 1.1–2.5, $p = 0.02$). Age and sex were not independent risk factors for MASLD. To assess for cohort effects, we ran additional analyses controlling for cohort rather than age category and found similar statistically significant results (data not shown).

6 | DISCUSSION

Our study of urban Latinx children of Mexican and Central American origins found exposure to household food insecurity at 4 years of age was associated with increased odds of MASLD in early to middle childhood. This was an independent association that persisted after adjusting for age at the time of MASLD assessment, sex and BMI *Z*-score at 2 years of age. To our knowledge, this is the first study associating exposure to household food insecurity with the development of MASLD in children. Our findings are consistent with recent adult studies that have found an increased risk of MASLD among adults with food insecurity.[12,13] This association complements earlier cross-sectional studies that found food insecurity among children with MASLD was not uncommon.[16,17] Our prospective birth cohort study demonstrates that early exposure to household food insecurity itself is a risk factor for MASLD in a high-risk pediatric population.

While our study is the first to document the association of early household food insecurity with MASLD in early to mid-childhood, others have found that children from socioeconomically deprived neighbourhoods may be at risk for an earlier onset of MASLD[38] and that those with MASLD and food insecurity are more likely to have other unmet social needs at future medical visits.[17] Children who grow up in neighbourhoods with higher socioeconomic disadvantage—based on a score derived from census data that includes the proportion of adults with primary education only, unemployment rates and the percent of people living in rented housing—have higher odds for developing MASLD in adulthood.[39] We found that 28.7% of households in our cohort reported living with food insecurity. This is significantly higher than what was reported by the USDA in 2020, which found a household food insecurity prevalence of 17.1% among Latinx families.[14] Notably, we assessed household food security and not individual child food security. Household food security indices measure food security at the level of the household, but does not assess food access issues that may be specific to the children living in the household. Children are often protected from reductions in food intake, even in households with very low food security,[14,40] as parents may prioritize children's food intake over their own. This is important because although children in food insecure households may not have reduced intake of nutritionally appropriate foods, their diet or stress response may still be altered enough to increase their risk for MASLD.

We hypothesize that early exposure to household food insecurity could potentially lead to increased risk for MASLD through multiple mechanisms. Previous studies have found associations between pediatric obesity and food insecurity based on diets of poor nutritional quality.[41] Food insecurity has also been linked to lower intake of fruits and vegetables and higher intake of energy dense, nutrient poor foods as well as high intake of fructose (from SSB intake),[41] which leads to increased fat directly into the liver. Although we did find an association between household food insecurity when the child was 4 years of age and fast food intake at 5 years of age, we did not find associations between SSB intake or fast food intake and MASLD, nor did we find an association between household food insecurity and SSB intake. This may be due to the relatively small size of our sample. Alternatively, exposure to household food insecurity may lead to irregular feeding patterns causing higher stress[42,43] and increased inflammation.[44,45] Children exposed to household food insecurity may also experience higher intake of less diverse foods and rapid cycles of fasting and high intake, which may result in altered gut-liver axis (change in microbiota)[46] and increased insulin resistance.[45] Additional research is needed to explore these potential mechanisms and develop early screening and prevention strategies.

Household food insecurity when the child was 4 years of age was also associated with higher child BMI *Z*-score at 2 years, lower birthweight *Z*-scores and shorter gestational duration. As we only assessed household food insecurity at one timepoint in this study, we were unable to evaluate if exposure to prenatal food insecurity or sustained exposure may further increase the risk for MASLD and impact growth trajectories from birth. Future longitudinal studies assessing food security at multiple timepoints are needed.

We found a high prevalence of MASLD in our cohort (27.2%), which is notable given that the median age of our participants was only 11 years. While this is higher than estimates from another study estimating a prevalence of 13% in US teenagers nationally,[2] our cohort was high risk given it is a Latinx cohort with high rates of obesity (36.0%). We found that early life overweight/obesity (BMI *Z*-scores >1) at 2 years of age were also independent risk factors for MASLD later in childhood. This is consistent with findings from other studies that have shown higher adiposity measures in mid-childhood and greater increases in adiposity in mid-childhood were associated with higher ALT levels.[47]

Our findings suggest that children with overweight or obesity in early childhood are likely at increased risk for MASLD later in childhood. The high prevalence of MASLD in our cohort also suggests that screening for MASLD should occur earlier in childhood than recommended in both the current American Academy of Pediatrics (AAP) and the North American Society of Pediatric Gastroenterology, Hepatology, and Nutrition (NASPGHAN) guidelines.[10,28] Both guidelines recommend to start screening children with obesity and those with overweight and the presence of cardiometabolic risk factors at 9–11 years of age.[10,28] The AAP guidelines also state that pediatricians may consider screening children with severe obesity for MASLD at 2–9 years of age by checking an ALT every 2 years.[28]

A key limitation to our study is that the definition of MASLD is not based on liver biopsy or MR imaging. However, it is not the standard of care[10] or feasible to perform biopsies or MRIs in population-based studies such as ours, which is composed primarily of healthy children and not children diagnosed with MASLD receiving care in subspecialty clinics. Studies have found that MASLD and even steatohepatitis are often present in children with obesity and mild or even normal ALT values.[48] The metabolic factors that we would expect to see in children with MASLD were associated with MASLD in our cohort (insulin resistance, elevated triglycerides, low HDL levels, high LDLs, higher blood pressures and waist circumferences). As such, ALT in the context of obesity is a reasonable surrogate marker. Given that children with MASLD in our study had a median ALT of 31 (IQR 27–55), we likely would have found an even stronger relationship between food insecurity and MASLD in a clinic or hospital-based sample of children with more severe MASLD or MASH. Moreover, we may be underestimating the rates of MASLD disproportionately in boys compared with girls as ALT values are less specific and sensitive in boys.[30]

Another limitation is that we have labs at one timepoint; thus, we could not assess ALT changes over time or the evolution of other potentially mediating factors like insulin resistance or systemic inflammation. Our conclusions are also limited by our small overall sample size (n = 136), limited number of cases with MASLD and associated relatively wide confidence intervals.

As our study is composed primarily of children in urban households of Mexican and Central American origins, our results may not be generalizable to all Latinx children. Finally, the two cohorts were recruited at different times and are composed of two different age groups, with the HEN cohort being recruited in 2006–2007 and the LEAD cohort being recruited in 2011–2013. This could have led to temporal changes in terms of economic stressors in San Francisco.

Our study also has several strengths. This is a longitudinal birth cohort of Latinx children from households experiencing low-income who are primarily of Mexican and Central American origins. This group is at known high risk for MASLD. There have been few longitudinal cohort studies on pediatric MASLD, well characterized in terms of their maternal and childhood risk factors.

7 | CONCLUSIONS

Ours is the first study to find that exposure to household food insecurity in early childhood (at 4 years of age) is independently associated with MASLD in early to middle childhood. Moreover, our cohort of children of Mexican and Central American origins had a high prevalence of both food insecurity and MASLD, suggesting a potential role for earlier screening for both in Latinx populations. By screening for food insecurity in addition to MASLD, pediatricians and pediatric sub-specialists could connect families to food resources in their communities. Programmes to address food insecurity may have beneficial effects in Latinx children living in households experiencing low income who are already at high risk for development of MASLD and warrant further investigation. Higher BMI *Z*-scores at 2 years of age were also associated with subsequent risk for MASLD suggesting a need for primary care providers to focus on early life weight management to prevent future metabolic disease.

In future work, it will be important to also assess whether and why chronic exposure to food insecurity may be associated with MASLD, especially given that food insecurity increased threefold in the COVID-19 pandemic among Latinx families.[49]

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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DATA AVAILABILITY STATEMENT

Data will be considered for sharing based on individual requests to the corresponding author.

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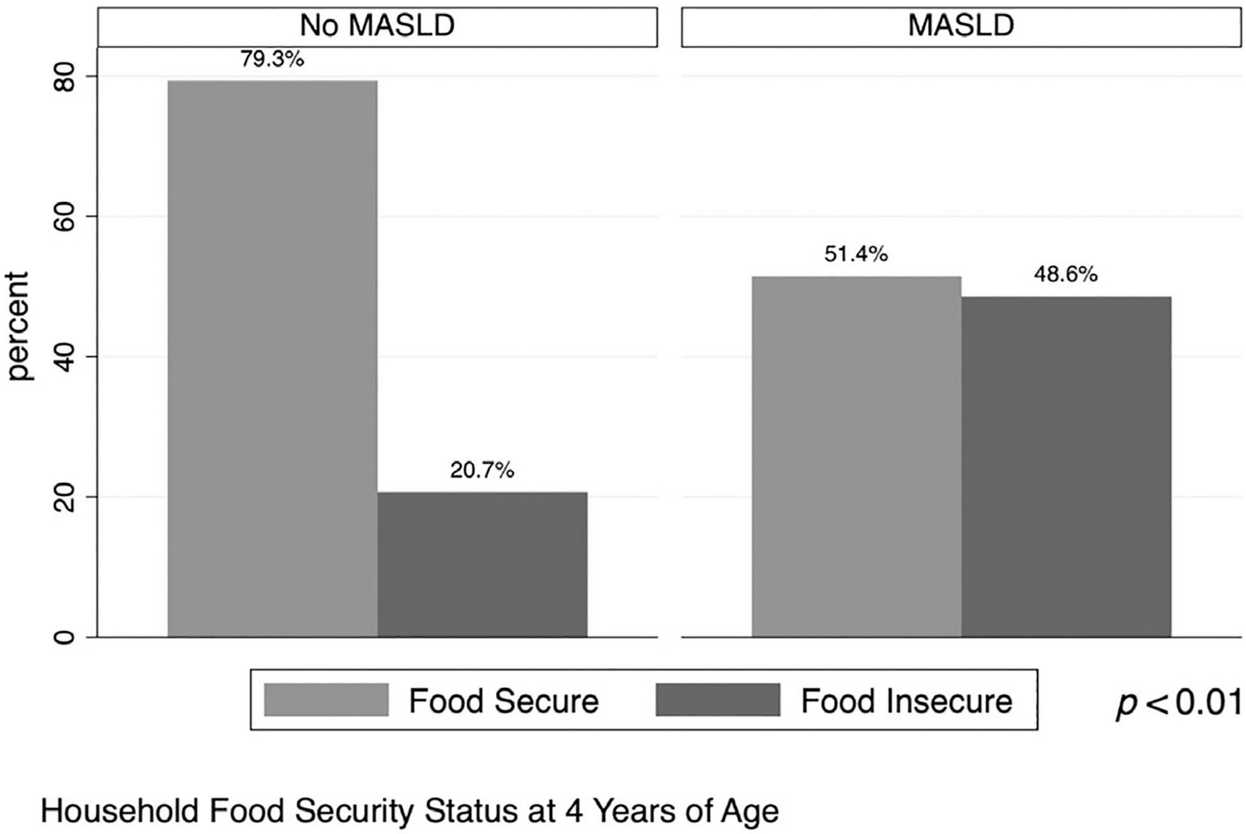

FIGURE 1.
Household food security by child MASLD status.

TABLE 1

Demographics, maternal and early childhood health characteristics, and child clinical values.

Characteristics	**Overall cohort** $N = 136$ *N* **(%) or median (IQR)**
Maternal demographics	
Maternal ethnicity (self-reported)	
Mexican	82 (59.9%)
Central American	49 (35.7%)
Other Hispanic	5 (0.03%)
Maternal primary language	
English	8 (5.8%)
Spanish	124 (91.2%)
Spanish and English	4 (2.9%)
Maternal health characteristics	
Maternal age at delivery (years)	27.0 (23.0–30.5)
Pre-pregnancy BMI (kg/m^2)	25.6 (23.0–29.4)
Pre-pregnancy BMI category	
BMI < 25 kg/m^2 (normal/underweight)	54 (39.7%)
BMI ≥ 25 kg/m^2 (overweight/obesity)	82 (60.3%)
Gestational hypertension	8 (5.8%)
Gestational diabetes mellitus	5 (3.6%)
WIC participation in pregnancy	128 (94.1%)
Early childhood characteristics	
Male sex	64 (47.0%)
Gestational age at birth (weeks)	39.4 (38.7–40.1)
Birthweight Z-score	−0.06 (−0.6–0.4)
BMI Z-score at 2 years of age	0.7 (−0.01–1.2)
BMI categories at 2 years of age	
Normal weight	86 (63.2%)
Overweight	27 (19.9%)

Characteristics	Overall cohort *N* = 136 *N* (%) or median (IQR)
Obesity	23 (16.9%)
Household food security (at age 4 years)	
Food secure	87 (71.3%)
Food insecure	35 (28.7%)
>02× sugar sweetened beverage drinks per week at 5 years of age	48 (35.3%)
Fast food >1× per week at 5 years of age	62 (51.7%)
Child clinical values at the time of MASLD assessment	
Age at MASLD assessment (years)	11.2 (7.0–11.5)
Age <10 years	43 (31.6%)
Age ≥10 years	93 (68.4%)
ALT (U/L)	17.0 (13.0–25.0)
AST (U/L)	27.0 (21.0–31.0)
HgbA1c (%)	5.3 (5.2–5.4)
Total cholesterol (mg/dL)	152.0 (140.0–176.0)
HDL (mg/dL)	54.0 (44.0–64.0)
LDL (mg/dL)	81.0 (68.0–92.0)
Triglycerides (mg/dL)	79.0 (58.0–125.0)
Insulin (mIU/mL)	12.7 (7.0–23.6)
Uric acid (mg/dL)	4.0 (3.3–4.6)
Systolic BP (mmHg)	99.2 (88.3–110.0)
Diastolic BP (mmHg)	61.5 (51.3–68.3)
BMI Z-score	1.3 (0.4–1.9)
Weight categories	
Normal weight	58 (42.7%)
Overweight	29 (21.3%)
Obesity	49 (36.0%)
Waist circumference (cm)	74.1 (64.6–86.3)
MASLD	37 (27.1%)

Abbreviations: ALT, alanine transaminase; AST, aspartate aminotransaminase; BMI, body mass index; HDL, high-density lipoprotein; HgbA1c, haemoglobin A1c; LDL, low-density lipoprotein; WIC, Women, Infants and Children.

TABLE 2

Demographics, child characteristics and clinical values by household food security status at 4 years of age.

	Food secure	**Food insecure**	
	***N* = 81 (66%)**	***N* = 41 (34%)**	
	***N* (%) or median (IQR)**	***N* (%) or median (IQR)**	***p* value**
Demographics			
Maternal ethnicity (self-reported)			0.03
Mexican	53 (65.4%)	19 (46.3%)	
Central American	27 (33.0%)	18 (43.9%)	
Other Hispanic	1 (1.0%)	4 (9.8%)	
Maternal primary language			0.96
English	4 (4.6%)	2 (5.7%)	
Spanish	80 (92.0%)	32 (91.4%)	
Spanish and English	3 (3.4%)	1 (2.9%)	
WIC in pregnancy	74 (91.4%)	40 (97.6%)	0.19
Early childhood characteristics			
Male sex	40 (49.0%)	18 (61.3%)	0.57
Gestational age, weeks	40.0 (39.0–40.7)	39.0 (38.0–39.4)	<0.01
Birthweight Z-score	0.1 (−0.5–0.6)	−0.4 (−0.9–0.1)	<0.01
BMI-Z score at 2 years of age	0.5 (−0.4–1.2)	0.9 (0.3–1.5)	0.03
>2× sugar sweetened beverage drinks per week at 5 years of age	27 (33.3%)	12 (29.3%)	0.21
Fast food >1× per week at 5 years of age	37 (45.7%)	20 (51.3%)	0.02
Child clinical values at the time of MASLD assessment			
Age at MASLD assessment (years)	11.2 (6.6–11.5)	11.2 (7.3–11.5)	0.42
Age ≥10 years	57 (70.4%)	28 (68.3%)	0.06
ALT (U/L)	17 (12–24)	19 (13–29)	0.11
AST (U/L)	26 (20–31)	28 (22–32)	0.12
HgbA1c (%)	5.4 (5.1–5.5)	5.4 (5.2–5.7)	0.41
Cholesterol (mg/dL)	154 (142–176)	144 (132–177)	0.12
HDL (mg/dL)	56 (45–65)	53 (40–61)	0.13
LDL (mg/dL)	83 (71–93)	75 (62–82)	0.02

	Food secure	Food insecure	
	N = 81 (66%)	*N* = 41 (34%)	
	N (%) or median (IQR)	*N* (%) or median (IQR)	*p* value
Triglycerides (mg/dL)	79 (58–115)	88 (56–131)	0.88
Insulin (mIU/mL)	13.6 (7.4–26.0)	13.3 (6.2–24.9)	0.71
Uric acid (mg/dL)	4.0 (3.3–4.6)	4.3 (3.4–4.7)	0.40
Systolic BP (mmHg)	98.8 (88–105.3)	109.5 (94.3–113.0)	0.01
Diastolic BP (mmHg)	61.5 (56.0–66.3)	65.7 (58.7–74.0)	0.11
BMI Z-score	1.3 (0.3–1.9)	1.0 (0.7–1.7)	0.14
Weight categories			0.78
Normal weight	33 (40.7%)	17 (41.4%)	
Overweight	18 (22.2%)	7 (17.1%)	
Obesity	30 (37.0%)	17 (41.4%)	
Waist circumference (cm)	75 (64.5–85.0)	74.3 (66.4–87.5)	0.88
MASLD	17 (21.0%)	17 (41.1%)	0.02

Abbreviations: ALT, alanine transaminase; AST, aspartate aminotransaminase; BMI, body mass index; HDL, high-density lipoprotein; HgbA1c, haemoglobin A1c; LDL, low-density lipoprotein; WIC, Women, Infants and Children.

TABLE 3

Cohort characteristics, maternal and early childhood risk factors by child metabolic dysfunction-associated steatotic liver disease (MASLD) status.

Characteristics	No MASLD $N = 99$ (73.8%) N (%) or median (IQR)	MASLD $N = 37$ (27.2%) N (%) or median (IQR)	*p* value
Maternal demographics			
Maternal ethnicity (self-reported)			0.58
Mexican	62 (62.6%)	20 (52.6%)	
Central American	33 (33.3%)	16 (42.1%)	
Other	4 (4.0%)	2 (5.0%)	
Maternal primary language			0.38
English	5 (5.1%)	3 (8.1%)	
Spanish	90 (90.9%)	34 (91.9%)	
Spanish and English	4 (4.0%)	0 (0%)	
Maternal health characteristics			
Maternal age at delivery (years)	27.0 (23.0–27.0)	26.0 (22.0–32.0)	0.50
Pre-pregnancy BMI (kg/m^2)	25.5 (22.8–28.4)	27.9 (24.4–33.0)	0.06
Pre-pregnancy BMI category			0.20
BMI < 25 kg/m^2 (underweight/normal)	43 (43.4%)	11 (29.7%)	
BMI ≥ 25 kg/m^2 (overweight/obese)	56 (56.6%)	26 (70.2%)	
Gestational hypertension	6 (6.1%)	2 (5.3%)	0.90
Gestational diabetes mellitus	3 (3.0%)	2 (5.3%)	0.50
WIC participation in pregnancy	92 (92.9%)	36 (97.3%)	0.30
Early childhood characteristics			
Male sex	43 (43.4%)	21 (56.8%)	0.17
Gestational age at birth (weeks)	39.7 (38.9–40.3)	39 (38.4–40.0)	0.09
Birthweight Z-score	0.06 (−0.6–0.6)	−0.1 (−0.6–0.1)	0.20
BMI Z-score at 2 years of age	0.5 (0.2–1.0)	1.1 (0.4–1.8)	<0.01
BMI category at 2 years of age			0.03
Normal weight	69 (69.7%)	17 (46.0%)	
Overweight	17 (17.2%)	10 (27.0%)	

Characteristics	No MASLD N = 99 (73.8%) N (%) or median (IQR)	MASLD N = 37 (27.2%) N (%) or median (IQR)	p value
Obesity	13 (13.1%)	10 (27.0%)	
Household food security (at age 4)			<0.01
Food secure	69 (79.3%)	18 (51.4%)	
Food insecure	18 (20.7%)	17 (48.6%)	
>2× sugar sweetened beverage drinks per week at 5 years of age	33 (33%)	15 (40%)	0.40
Fast food >1 × per week at 5 years of age	43 (51%)	19 (53%)	0.90
Clinical values at the time of MASLD assessment			
Age at MASLD assessment (years)	11.1 (6.3–11.5)	11.4 (10.1–11.6)	0.03
Age category			0.26
Age <10 years	34 (34.4%)	9 (24.3%)	
Age ≥10 years	65 (65.7%)	28 (75.7%)	
ALT (U/L)	15.0 (12.0–18.0)	31.0 (27.0–55.0)	<0.01
AST (U/L)	25.0 (20.0–30.0)	31.5 (26.0–40.0)	<0.01
HgbA1c (%)	5.4 (5.1–5.5)	5.3 (5.2–5.4)	0.60
Total cholesterol (mg/dL)	149.0 (140.0–170.0)	167.0 (140.0–185.0)	0.05
HDL (mg/dL)	56.0 (48.0–67.0)	45.0 (38.0–56.0)	<0.01
LDL (mg/dL)	80.0 (67.0–92.0)	87.0 (75.0–97.0)	0.13
Triglycerides (mg/dL)	69.0 (51.0–103.0)	144.0 (87.0–194.0)	<0.01
Insulin (mIU/mL)	11.8 (6.8–19.0)	26.8 (14.0–43.2)	<0.01
Uric acid (mg/dL)	4.0 (3.2–4.5)	4.7 (3.7–5.9)	<0.01
Systolic BP (mmHg)	93.8 (76.3–103.3)	109.5 (95.2–112.5)	<0.01
Diastolic BP (mmHg)	58.5 (46.7–62.8)	67.3 (63.0–73.5)	<0.01
BMI Z-score	0.9 (0.2–1.6)	2.1 (1.6–2.3)	<0.01
Waist circumference (cm)	70.5 (63.0–79.5)	86.5 (73.7–96.0)	<0.01

Abbreviations: ALT, alanine transaminase; AST, aspartate aminotransaminase; BMI, body mass index; HDL, high-density lipoprotein; HgbA1c, haemoglobin A1c; LDL, low-density lipoprotein; WIC, Women, Infants and Children.

TABLE 4

Multivariable model: Unadjusted and adjusted analyses of factors associated with pediatric metabolic dysfunction-associated steatotic liver disease.

	Unadjusted OR (95% CI)	***p*-value**	**Adjusted[a] OR (95% CI)**	***p*-value**
Household food insecurity at 4 years of age (ref = household food security)	1.9 (1.2–2.9)	<0.01	3.7 (1.5–9.0)	<0.01
Age ≥10 years (ref = <10 years)	1.6 (0.7–3.8)	0.27	1.0 (0.4–2.9)	0.95
Female sex (reference = male sex)	0.6 (0.3–1.3)	0.17	0.7 (0.3–1.8)	0.47
BMI Z-score at 2 years of age	1.7 (1.2–2.5)	<0.01	1.6 (1.1–2.5)	0.02

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.

[a]Adjusted for all variables in the table.