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# Biomarker-predicted sugars intake compared with self-reported measures in US Hispanics/Latinos: Results from the HCHS/SOL SOLNAS Study

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**Conflict of Interest**

The authors have no conflict of interest to disclose.

**Authorship**

YMR and JMB designed research; WWW, PAS, AMSR, DSA, MDG, MS, LVH, AAF, YMR conducted research and provided essential materials; MJ, PAS, NT, DSA, and JMB developed the analytic approach and analyzed data; and JMB, JRK, JS, JWR and YMR wrote the paper. All authors read and approved the final manuscript. The authors thank the staff and participants of HCHS/SOL for their important contributions. Investigators website - http://www.cscc.unc.edu/hchs/

**Ethical Standards Disclosure**

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Albert Einstein College of Medicine Institutional Review Board. Written informed consent was obtained from all subjects.

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## Abstract

**Objective—**Measurement error in self-reported total sugars intake may obscure associations between sugars consumption and health outcomes, and the sum of 24-hr urinary sucrose and fructose may serve as a predictive biomarker of total sugars intake.

**Design—**The Study of Latinos: Nutrition & Physical Activity Assessment Study (SOLNAS) was an ancillary study to the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) cohort. Doubly labeled water (DLW) and 24-hr urinary sucrose and fructose were used as biomarkers of energy and sugars intake, respectively. Participants' diets were assessed by up to three 24-hr recalls (88% had two or more recalls). Procedures were repeated approximately six months after the initial visit among a subset of 96 participants.

**Setting—**Four centers (Bronx, NY; Chicago, IL; Miami, FL; San Diego, CA) across the United States

**Subjects—**477 men and women aged 18–74 years.

**Results—**The geometric mean of total sugars intake was 167.5 (95% CI: 154.4–181.7) g/day for the biomarker-predicted and 90.6 (95% CI: 87.6–93.6) g/day for the self-reported total sugars intake. Self-reported total sugars intake was not correlated with biomarker-predicted sugars intake ($r=-0.06$, $P=0.20$, $n=450$). Among the reliability sample ($n=90$), the reproducibility coefficient was 0.59 for biomarker-predicted and 0.20 for self-reported total sugars intake.

**Conclusions—**Possible explanations for the lack of association between biomarker-predicted and self-reported sugars intake include measurement error in self-reported diet, high intra-individual variability in sugars intake, and/or urinary sucrose and fructose may not be a suitable proxy for total sugars intake in this study population.

### Keywords

sugars; doubly labeled water; self-report; urinary sucrose and fructose biomarkers; Hispanics/Latinos

## Introduction

According to the American Heart Association, excessive dietary sugars intake, especially in the form of fructose consumption, may contribute to obesity, insulin resistance, Type 2 diabetes, hypertension, and dyslipidemia [(1)]. Possible pathways potentially explaining the role of dietary sugars in increasing cardiometabolic risk include: 1) excess energy intake;

and/or 2) high dietary glycemic load leading to inflammation, insulin resistance, and impaired beta-cell function [1, 2]. US Hispanics/Latinos are 25% (95% CI= 13–38%) more likely to report sugar-sweetened beverage consumption compared to non-Hispanic/Latino adults per NHANES 2007–2008 data[3]. Type 2 diabetes is highly prevalent among Hispanics/Latinos in the US, with wide variability based on Hispanic/Latino background, ranging from 10.2% in South Americans to 18.3% in Mexicans, P<0.0001[4].

Measurement error in self-reported intake has impeded progress in definitively addressing diet-disease hypotheses[5–9]. Identified strategies for mitigating measurement error include statistical approaches that combine two dietary assessment approaches (*e.g.* food frequency questionnaire (FFQ) and 24-hr recall (24HR) or biomarker with self-reported diet data [10, 11], integration of validated biomarkers into epidemiological studies, and the development and validation of new biomarkers that characterize dietary components [12, 13]. Nutrient biomarkers have been classified as recovery, concentration, predictive, or replacement [14], depending upon whether the biomarker reflects an absolute level of intake or is correlated with dietary intake (*i.e.* recovery *vs.* concentration), the degree to which the biomarker is recovered and quantifiable (*i.e.* predictive) [15], or is used as a surrogate measure of intake for nutrients difficult to assess or with no food composition data available (*i.e.* replacement).

Methodological approaches for incorporating biomarkers within epidemiological studies have been developed [10, 11, 16], and applications of these approaches have strengthened associations in diet-disease analyses[17–20]. With combined biomarker and self-reported dietary data, the sample size requirement for estimating diet-disease associations may be reduced by 20–50% compared to self-reported intake alone [11]. A predictive biomarker for total sugars intake (*i.e.*, sum of fructose and sucrose in 24-hr urine) developed in two controlled feeding studies in the United Kingdom showed that the sum of urinary sucrose and fructose in 24-hr urine was significantly correlated with total sugars (r=0.841; P < 0.001) and sucrose intake (r=0.773; P=0.002) [15]. This biomarker has been recently integrated into two US-based biomarker studies with free-living individuals as a reference instrument against FFQ-, 24HR- and food record (FR)-based sugars intake [21, 22]. The objective of this study was to compare the consumption of sugars estimated from self-report with values derived from a biomarker of sugars intake nested within a large observational cohort study of Hispanic/Latino adults living in the United States.

## Methods

### Study Description

The Study of Latinos: Nutrition & Physical Activity Assessment Study (SOLNAS), an ancillary study of the Hispanic Community Health Study/Study of Latinos (HCHS/SOL), included Hispanic/Latino men and women aged 18 to 74 years at HCHS/SOL baseline who were recruited from four centers (Bronx, NY; Chicago, IL; Miami, FL; San Diego, CA) across the United States, as previously described[23–25]. After excluding SOLNAS participants having incomplete (<500 mL per day) or missing urine samples (n=26 for the primary study and 6 for the reliability study), the analytic sample was 450 for the primary sample and 90 for the reliability sample. Dietary recalls were excluded at each time point if

reported daily energy intake was <600 or >3000 kcal for women or <800 or >4000 kcal for men (Figure 1)[26].

### Energy expenditure and self-reported physical activity assessment

Energy expenditure was measured using a doubly labeled water (DLW) protocol [27]. Following the collection of a baseline urine sample, participants ingested a DLW mixture that provided 1.38 g of 10 atom percent $^{18}O$ labeled water and 0.086 g of 99.9% deuterium labeled water per kilogram body weight and provided in-clinic spot urines at 3 and 4 hours [28]. Participants ages ≥60 years provided a blood sample 3 hours post-isotope to allow adjustment for age-related post void urine retention. An additional post-dose sample was collected on day 12 of the DLW protocol. Self-reported physical activity was assessed by the Global Physical Activity Questionnaire that was developed by the World Health Organization to quantify time spent in moderate and vigorous levels of physical activity at work, travel, and leisure time [29, 30]. Twenty percent of the participants (n=96) repeated the protocol to obtain reliability measures.

### Self-reported sugars intake assessment

Self-reported sugars intake was estimated using the National Cancer Institute (NCI) method [31], using all available data to estimate usual dietary intake by combining up to five 24HR recalls (Figure 1). In-person 24HR recalls were conducted at the HCHS/SOL baseline, SOLNAS baseline, and the SOLNAS reliability study visit (Supplementary Table 1). Interviews were conducted in Spanish or English depending on the participant's preference with the Nutrition Data System for Research (NDS-R) software (Version 11) developed by the Nutrition Coordinating Center at the University of Minnesota, which uses the multiple-pass method and has a database with >18,000 foods. As described by Tooze *et al* [32], the NCI method for estimating usual intake involved two steps. The first step (NCI MIXTRAN macro) specifies the consumption-day amount using linear regression on a transformed scale, with a person-specific effect adjusted for sex, age, Hispanic/Latino background, field center, weekend (including Friday), self-reported intake amount (more, same, or less than usual amount) and sequence (*i.e.* Figure 1, first through fifth recall). The second step (NCI INDIVINT macro) calculates the individual's predicted usual intake using parameter estimates from the first step.

### Biomarker-predicted energy assessment

The urine and plasma samples collected within the DLW protocol from SOLNAS participants were analyzed by gas-isotope-ratio mass spectrometry to assess energy expenditure [33]. The isotopic data were converted to energy expenditure values based on an energy equivalent of 1 L of $CO_2$ to be 3.815/RQ + 1.2321 where RQ is the respiratory quotient equal to 0.86, a standard among populations consuming a Western diet which is based on a high fat diet[25, 34].

### Biomarker-predicted sugars assessment

At SOLNAS baseline, participants collected one 24-hr urine that was analyzed for sucrose and fructose. Urinary sucrose and fructose were measured by liquid chromatography mass

spectrometry (LC-MS) at the University of Hawaii Cancer Center [35]. Urine samples (20 μL) mixed with internal standards were dried using nitrogen and reconstituted in 100 μL MeOH,. The redissolved sample was centrifuged and the supernatant (10 μL) was injected into the LCMS system (model Accela ultra HPLC coupled to a TSQ Quantum Ultra tandem mass spectrometer with Xcalibur™ software, ThermoFisher, San Jose, CA). Chromatographic separations were performed on a ZIC®-HILIC column (100 mm × 2.1 mm, 3 μm; Merck KGaA, Darmstadt, Germany) by gradient elution using 0.1% formic acid in MeCN and 0.1% formic acid in $H_2O$ at a flow rate of 0.3 mL/minute. Masses were continuously monitored by APCI in negative mode and selected ion monitoring by extracting the respective accurate mass-to-charge (*m/z*) ratios.

Among a 10% blinded Quality Control (QC) sample (collected about once per month from among SOLNAS 24-hr urine samples (n=50)), the coefficients of variation were 11.7% for fructose and 8.0% for sucrose. Per an internal laboratory QC (n=11), intra-day coefficients of variation were 4.6% ± 2.2% for fructose and 5.8% ± 6.9% for sucrose, and inter-day coefficients of variation were 10.5% for both fructose and sucrose.

We used the calibration equation below (i) for total sugars biomarker, previously developed based on data from a feeding study [15, 21], to calibrate the biomarker (*i.e.* sum of 24-hr urine sucrose and fructose), and to derive biomarker-predicted sugars (BPS) intake in SOLNAS participants:

$$PM_{ij}=M_{ij}-1.67-0.02\times S_i+0.71\times A_i \quad \text{(i)}$$

where:
$\mathrm{PM}=\log-\text{transformed calibrated biomarker},\ i.e.,\ \text{BPS intake for individual}\ i\ \text{on day}\ j,$
M = log-transformed (sum of 24-hr urine fructose and sucrose), S = sex (0 for men, 1 for women), A= log-transformed age.

## Statistical analysis

Both self-reported and BPS intake were log-transformed to improve normality. Geometric means and 95% confidence intervals (95% CI) were computed for self-reported and BPS intake, overall and by selected participant characteristics. Participant characteristics (mean and standard deviation for continuous and n (%) for categorical variables) were summarized by quartile of BPS intake. We assessed the correlations of BPS (g/d) with self-reported sugars intake (g/d) using Spearman correlation coefficients. Among the reliability participants, Spearman correlations were calculated to assess the relationship between repeated measures of self-reported and BPS intake.

To examine the sensitivity of the results to the analytic approaches used, results were stratified by accuracy of reporting status, with “concordance” defined by self-reported energy intake within 25% of energy expenditure estimated by DLW. Analyses were repeated using the “raw” sum of 24-hr urine fructose and sucrose (*i.e.* un-calibrated biomarker), rather than using BPS, *i.e.*, calibrated biomarkers, as a measure of objective sugars intake. Furthermore, BPS was correlated to self-reported estimates of total sugars intake from a

single 24HR recall which corresponded to the time-point closest to the urine collection (*e.g.* 24HR administered within 7 days of 24-hr urine collection) rather than using the NCI method to estimate usual intake as the measure of sugars intake. Statistical analyses were conducted using SAS 9.3 software (SAS Institute, Cary, NC).

## Results

Overall, geometric mean self-reported total sugars intake was 90.6 (95% CI: 87.6–93.6) g/day *vs.* 167.5 (95% CI: 154.4–181.7) g/day of biomarker-predicted total sugars intake (Table 1). Whereas self-reported total sugars intake was not associated with participant characteristics, BPS intake was significantly associated with age and ethnicity (Table 2). There was a non-significant trend for a higher proportion of obese individuals and those with lower education level to be in the highest BPS quartile. BPS intake was also higher among older participants and Puerto Ricans. Self-reported total sugars intake was not correlated with BPS (r=0.06, P=0.20).

The self-reported total sugars intake and BPS intake were not related, irrespective of whether energy expenditure estimated by DLW was within 25% of self-reported total energy intake (P>0.05) (Table 3). Usual energy intake was correlated with energy expenditure measured with the DLW method, and it was more highly correlated among true reporters compared to participants who were not classified as concordant reporters (r=0.79 *vs.* r=0.54, P<0.0001). Among the participants in the 20% reliability subsamples, who repeated the entire protocol about 6 months after the SOLNAS baseline visit, the repeated measures of BPS intake at baseline and 6 months were more highly correlated than repeated self-reported total sugars intake (r=0.59 *vs.* r=0.20, for gender-specific reliability coefficients see Figure 2).

Sensitivity analyses also demonstrated the lack of an association between urinary fructose and sucrose and self-reported total sugars intake. Among the primary study participants, the correlation between the “raw”/un-calibrated sum of 24HR urinary fructose and sucrose and NCI-based sugars intake was r=0.03, P=0.58, and the agreement between quartiles of the raw sum and BPS was high (Kappa=0.72, P<0.0001, Supplementary Table 2). Similarly, the correlation between BPS and a single 24HR corresponding to the time-point closest to the urine collection rather than using the NCI method to estimate usual intake as the measure of self-reported total sugars intake was r=0.02, P=0.70. Within the reliability study, the correlation between BPS and a single 24HR corresponding to the time-point closest to the urine collection was r=0.36, P<0.0001; the association was stronger in men (r=0.63, P<0.001) than in women (r=0.27, P=0.04) (Supplementary Table 3).

## Discussion

Among a sizable, diverse sample of Hispanics/Latinos, BPS intake was not correlated with self-reported total sugars intake. Whereas BPS was correlated with age and ethnicity, self-reported total sugars intake was unrelated to participant characteristics. Contrary to expectation, there was no significant association between body mass index and BPS[36]. Using the sugars biomarker measured in spot urines, the European Prospective Investigation

of Cancer Norfolk reported positive associations between sucrose intake and obesity [37, 38], and a randomized, crossover trial in 10 normal weight and 9 overweight/obese participants suggested BMI does not affect the validity of the biomarker[39]. As this biomarker, so far, has not been validated for use among Hispanics/Latinos, we cannot definitively quantify the measurement error in the self-reported total sugars intake versus BPS intake. However, we conducted further analyses to better understand the reasons for the observed low correlations between self-reported and BPS intake. Using the recovery biomarker for energy intake based on DLW data, just over half of the sample (53%) was categorized as concordant (*i.e.* self-reported energy intake values were within 25% of biomarker values), but there was no association between self-reported and BPS intake when results were restricted to this subset.

Possible explanations for the lack of any association between BPS and self-reported sugars intake include measurement error in self-reported sugars intake, variability in sugars intake necessitating multiple 24HR recalls and measures of urinary sucrose and fructose to accurately estimate usual intake, and/or the lack of evidence to support the role of urinary sucrose and fructose as a valid proxy for total sugars intake in this study population. Measurement error in the reporting of energy and protein has been well established in several studies comparing self-reported intake to recovery biomarkers [5, 10, 16]. Other studies have nested the predictive urinary sucrose and fructose biomarker into validation studies to compare self-reported intake and biomarker-predicted intake of total sugars [21]. The Observing Protein and Energy Nutrition (OPEN) study reported that total sugars intake measured by both FFQ and 24HR recall was associated with large measurement error among 484 participants aged 40 to 69 yr [21]. In the Women's Health Initiative Nutrition and Physical Activity Assessment Study (NPAAS) (n=450), self-reported sugars intake was substantially, and roughly equally, misreported whether measured by FFQ, 4-day food record, or 24HR recall [21]. Geometric means of BPS in NPAAS and SOLNAS were similar: (173.9 g/day (95% CI 142.9, 211.6) *vs.* 167.5 g/day (154.4, 181.7), respectively [21]. The biomarker-prediction equation used in ours and each of these validation studies was derived from a highly controlled feeding study among 7 men and 6 women in the United Kingdom aged 23–66 [15, 21, 40]. We noted a strong positive association between the BPS and age (Table 1), which may be due to an overcorrection for age at the higher age ranges. In analyses where we did not apply the biomarker-prediction equation and relied on the sum of urinary sucrose and fructose, associations between age and self-reported intake were null. Data from a controlled feeding study including participants representative of the age, race/ethnicity, and BMI of this cohort would inform whether the biomarker-prediction equation is generalizable or needs modification based on these or other participant characteristics.

Whereas recovery biomarkers (*i.e.* doubly labeled water and 24-hr urinary nitrogen) are unbiased reference instruments that reflect an absolute level of intake, predictive biomarkers, such as 24-hr urinary sucrose and fructose, can also be used as reference validation instruments after being calibrated to account for bias in the biomarker, estimable from a feeding study against known intake [15]. We did not observe significant correlations between self-reported sugars intake and sucrose and fructose based on urinary measurements, even when restricting the analysis to individuals who reported energy intake within 25% of the DLW value. Another possibility for the lack of correlation between self-reported and BPS intake is that high intra-individual variation in sugars intake would necessitate multiple days

of measurement in order to estimate usual intake of total sugars. Among the subsample of reliability study participants, the reproducibility of self-reported sugars intake was much lower than the reproducibility of the urinary sucrose and fructose biomarkers. Furthermore, the self-reported intake from the 24-HR closest to the urine collection and BPS was significant among reliability participants ($r=0.36$, $P<0.001$, $n=84$). However, restricting the analysis to individuals having 24HR within one week of the urinary sucrose and fructose biomarker measurement did not result in significant correlations with self-reported sugars intake. Possible explanations include that the reliability participants were more accurate reporters of dietary intake and more compliant with the urine collection protocols compared to the rest of the SOLNAS participants. Since the equation for predicting biomarker-based sugars intake was developed based on a small sample of individuals in the United Kingdom, we examined correlations between both the "raw" sum of urinary sucrose and fructose in addition to applying the biomarker-prediction equation, but this did not substantively alter our results.

Strengths of this study include applying a predictive biomarker that has been validated in controlled feeding studies to an ethnically diverse cohort, representing both genders, of Hispanics/Latinos in the United States, as well as a wide range of other factors previously demonstrated to be associated with measurement error in self-reported diet intake, such as age and body mass index. The substantial sample size allowed conduct of several sensitivity analyses to ascertain whether our findings were influenced by the characterization of self-reported intake (*i.e.* usual intake per NCI method or restricting to 24HR within one week of the 24-hr urine collection time point), and level of concordance between DLW and self-reported energy intake. Our ability to make inferences about the magnitude of measurement error in self-reported sugars intake using the biomarker in this study population is limited. Highly controlled feeding studies with participants representative of the HCHS/SOL population would better characterize the application of this biomarker among Hispanics/Latinos.

In conclusion, in comparing a predictive biomarker of sugars intake among a diverse sample of Hispanics/Latinos, no significant associations were detected between the self-reported and biomarker-predicted sugars intake. Clinical studies that allow for the control of factors such as the amount of total sugars intake, the optimal time frame between sugars intake and biomarker measurement, and health are needed to better determine the potential use of urinary sucrose and fructose as a biomarker of total sugars intake.

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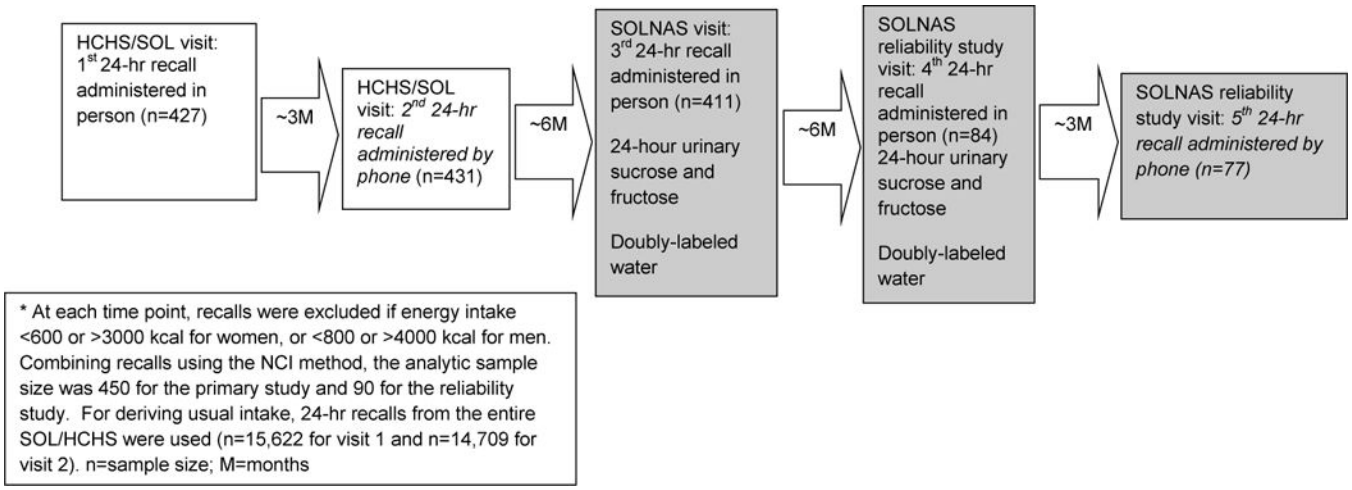


**Figure 1.**

Study Flow Diagram: Estimating self-reported dietary intake using the NCI Method and objective dietary intake using biomarkers of energy and sugars intake within the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) Cohort and Study of Latinos/ Nutrition & Physical Activity Assessment Study (SOLNAS)*

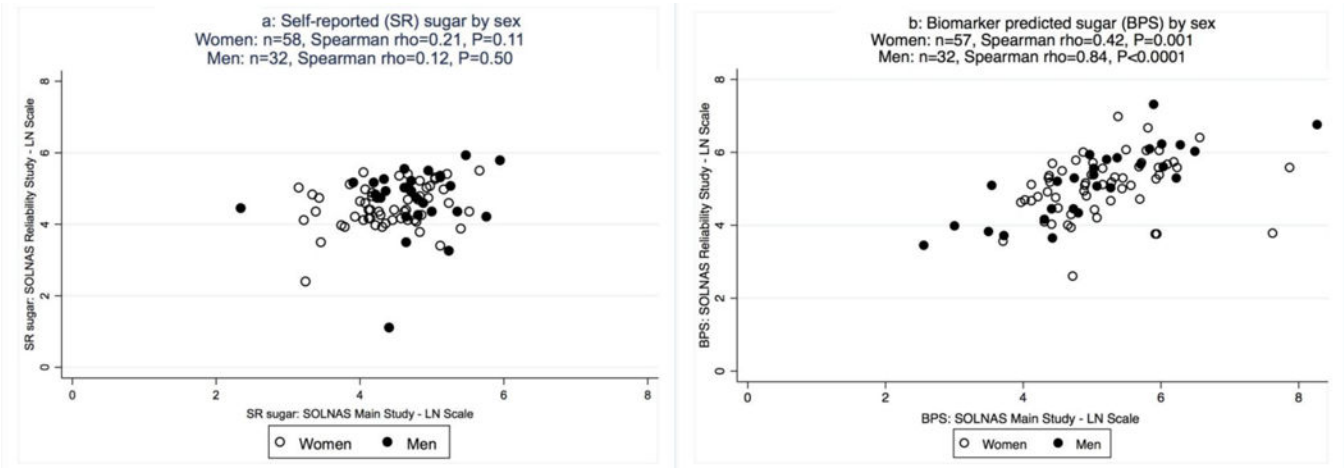


**Figure 2.**

Reproducibility of (2a) self-reported (2b) biomarker-predicted sugars intake at the SOLNAS main and reliability study visits

## Table 1

Geometric mean (95% Confidence Interval) of self-reported and biomarker-predicted sugars intake in SOLNAS (n=450)

| | n | Self-reported sugars intake (g/day)* | Biomarker-predicted sugars intake (g/day)* |
|---|---|---|---|
| Overall | 450 | 90.6 (87.6, 93.6) | 167.5 (154.4, 181.7) |
| Age, y | | | |
| 18–44 | 172 | 95.2 (90.4, 100.3) | 116.2 (101.5, 133.0) |
| 45–64 | 252 | 88.4 (84.5, 92.5) | 205.6 (186.6, 226.6) |
| 65+ | 26 | 82.0 (72.0, 93.4) | 257.1 (183.9, 359.3) |
| Sex | | | |
| Women | 276 | 83.5 (80.5, 86.6) | 157.6 (142.8, 174.0) |
| Men | 174 | 103.0 (97.0, 109.2) | 184.3 (160.0, 212.3) |
| Language of Interview | | | |
| English | 105 | 99.1 (92.4, 106.3) | 155.3 (129.4, 186.3) |
| Spanish | 345 | 88.1 (84.9, 91.4) | 171.3 (156.4, 187.7) |
| Weight Status | | | |
| Underweight (<18.5) | 4 | 80.8 (44.7, 146.1) | 203.0 (83.8, 492.0) |
| Normal (18.5–24.9) | 85 | 101.9 (95.2, 109.1) | 135.4 (112.4, 163.1) |
| Overweight (25–29.9) | 180 | 87.8 (83.6, 92.3) | 171.2 (151.9, 193.0) |
| Obese (≥30) | 181 | 88.5 (83.7, 93.7) | 180.2 (157.0, 207.0) |
| Hispanic/Latino Background | | | |
| Central American | 50 | 87.6 (79.0, 97.2) | 170.6 (129.9, 224.1) |
| Cuban | 65 | 82.4 (75.6, 89.8) | 186.1 (152.7, 226.8) |
| Dominican | 47 | 70.9 (64.5, 78.0) | 138.2 (97.6, 195.8) |
| Mexican | 135 | 98.8 (93.8, 104.1) | 153.3 (133.1, 176.7) |
| Puerto Rican | 115 | 94.0 (87.6, 100.9) | 198.9 (170.1, 232.6) |
| South American | 38 | 98.3 (88.3, 109.5) | 140.3 (114.5, 171.9) |
| Income | | | |
| Low income(<$30,000) | 299 | 91.3 (87.7, 95.1) | 172.8 (156.5, 190.7) |
| High income (≥$30,000) | 119 | 90.7 (85.0, 96.8) | 157.7 (133.9, 185.6) |
| Missing | 32 | 83.0 (73.3, 94.1) | 156.4 (112.2, 218.0) |
| Education | | | |
| Less than high school | 143 | 89.8 (84.7, 95.2) | 199.1 (170.8, 232.1) |
| High school equivalent | 112 | 93.5 (87.1, 100.5) | 163.6 (139.5, 191.9) |
| Greater than high school | 195 | 89.4 (85.2, 93.9) | 149.4 (132.7, 168.3) |

**Table 2**

Characteristics of SOLNAS participants by quartile of biomarker-predicted total sugars intake, SOLNAS (n=450)

| Characteristics | Q1 n=113 | Q2 n=112 | Q3 n=112 | Q4 n=112 | P-value |
|---|---|---|---|---|---|
| Biomarker-predicted total sugars intake, g/day, range | 6.5–104.5 | 104.7–168.3 | 169.4–276.0 | 277.8–2921.2 | |
| Self-reported Intake, NCI Method, mean (SD): | | | | | |
| Total Sugars Intake, g/day | 98 (32) | 96 (34) | 97 (39) | 95 (35) | 0.9 |
| Energy Intake, kcal/day | 1951 (476) | 1905 (490) | 1884 (511) | 1868 (492) | 0.41 |
| Energy Expenditure by DLW (mean (SD), kcal/d | 2368 (481) | 2368 (524) | 2439 (504) | 2518 (544) | 0.10 |
| Age (mean, (SD)), y | 39 (13) | 46 (12) | 48 (12) | 52 (11) | **<0.0001** |
| Gender (n, %) | | | | | 0.54 |
| Female | 74 (65.5%) | 71 (63.4%) | 67 (59.8%) | 64 (56.6%) | |
| Male | 39 (34.5%) | 41 (36.6%) | 45 (40.2%) | 49 (43.4%) | |
| Weight Status (n, %) | | | | | 0.41 |
| Underweight (<18.5) | 0 (0.0%) | 1 (0.9%) | 2 (1.8%) | 1 (0.9%) | |
| Normal (18.5–24.9) | 28 (24.8%) | 25 (22.3%) | 16 (14.3%) | 16 (14.2%) | |
| Overweight (25–29.9) | 43 (38.1%) | 45 (40.2%) | 48 (42.9%) | 44 (38.9%) | |
| Obese (≥30) | 42 (37.2%) | 41 (36.6%) | 46 (41.1%) | 52 (46.0%) | |
| Hispanic/Latino background (n, %) | | | | | **0.04** |
| Central American | 16 (14.2%) | 10 (8.9%) | 10 (8.9%) | 11 (9.7%) | |
| Cuban | 15 (13.3%) | 11 (9.8%) | 11 (9.8%) | 13 (11.5%) | |
| Dominican | 15 (13.3%) | 10 (8.9%) | 18 (16.1%) | 22 (19.5%) | |
| Mexican | 37 (32.7%) | 39 (34.8%) | 34 (30.4%) | 25 (22.1%) | |
| Puerto Rican | 21 (18.6%) | 26 (23.2%) | 29 (25.9%) | 39 (34.5%) | |
| South American | 9 (8.0%) | 16 (14.3%) | 10 (8.9%) | 3 (2.7%) | |
| Income (n, %) | | | | | 0.36 |
| Low Income(<$30,000) | 74 (65.5%) | 65 (58.0%) | 81 (72.3%) | 79 (69.9%) | |
| High Income (≥$30,000) | 29 (25.7%) | 38 (33.9%) | 25 (22.3%) | 27 (23.9%) | |
| Missing | 10 (8.9%) | 9 (8.0%) | 6 (5.4%) | 7 (6.2%) | |
| Educational level (n, %): | | | | | 0.56 |
| Less than high school | 32 (28.3%) | 31 (27.7%) | 37 (33.0%) | 43 (38.1%) | |
| High school equivalent | 26 (23.0%) | 31 (27.7%) | 30 (26.8%) | 25 (22.1%) | |

| Characteristics | Q1 n=113 | Q2 n=112 | Q3 n=112 | Q4 n=112 | P-value |
|---|---|---|---|---|---|
| Greater than high school | 55 (48.7%) | 50 (44.6%) | 45 (40.2%) | 45 (39.8%) | |
| Smoking, (n,%) | | | | | 0.22 |
| Never | 79 (69.9%) | 66 (58.9%) | 65 (58.0%) | 58 (51.8%) | |
| Past | 17 (15.0%) | 22 (19.6%) | 22 (19.6%) | 28 (25.0%) | |
| Current | 17 (15.0%) | 24 (21.4%) | 25 (22.3%) | 26 (23.2%) | |
| Self-reported Physical Activity *, (mean (SD)), min/wk | 439 (684) | 580 (1019) | 675 (993) | 461 (735) | 0.15 |

* Self-reported physical activity is the total amount of time spent doing some form of physical activity for work, transportation, recreation, and sedentary behavior in a week from the modified Global Physical Activity Questionnaire (GPAQ) (available at https://www2.cscc.unc.edu/hchs/system/files/forms/UNLICOMMPhysicalPAE02182008.pdf).

**Table 3**

Spearman correlations between self-reported and biomarker-based intake for energy and sugar intake by concordance with doubly-labeled water.*

| Concordance | N | Energy intake, kcal/d | P-value | Total Sugars, g/day | P-value |
|---|---|---|---|---|---|
| Concordant | 234 | 0.79 | <0.0001 | 0.04 | 0.59 |
| Discordant | 210 | 0.54 | <0.0001 | −0.06 | 0.37 |

*Concordance= Reported energy intake was within 25% of energy intake measured with the doubly labeled water method.