

# Clustering Methods to Empirically Derive Dietary Patterns in the United States

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August 3, 2020

# Outline

- 1 Hispanic Community Health Study/Study of Latinos
- 2 Dietary Consumption data
- 3 HCHS/SOL Analysis of FPQ data
- 4 Analysis of Dietary Recall data
- 5 Discussion

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# Hispanic Community Health Study/Study of Latinos (HCHS/SOL)



- Multi-center epidemiologic study on cardiometabolic health in Hispanic/Latino populations
- Participants aged 18-74 years of age
- Data collection: Baseline (2008-2011), Visit 2 (2015-2017)
- Field centers: Bronx, Chicago, Miami, San Diego
- Hispanic/Latino origin: Cuban, Puerto Rican, Dominican, Mexican, Central/South American

# Why do we care about diet?

- Poor diet is the leading cause of morbidity and mortality in the United States
- Dietary intake is a modifiable exposure



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# HCHS/SOL Dietary Data: Food Propensity Questionnaire

- Queried consumption of 129 foods and beverages in the past year
- captures both episodically and frequently consumed foods
- 12 frequency consumption response levels collapsed to five categories (servings per day)



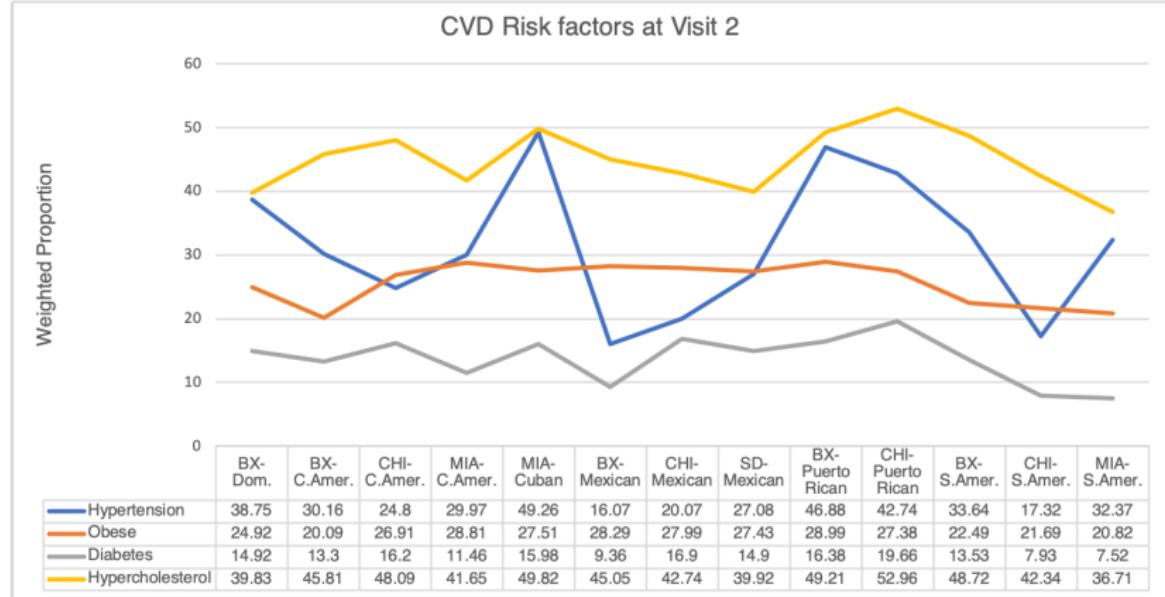
- Collapsed food variables
  - Binary: no consumption, any consumption (15)
  - Tertiary: no consumption, monthly, weekly/daily (48)
  - Quarternary: no consumption, monthly, weekly, daily (51)
  - non-collapsed (10)

# HCHS/SOL Dietary Data: Dietary Recall

Two 24-hour dietary recalls

- quantify amount of daily consumption
- 16,000+ foods → 165 food variables → 52 food groups
- summarized as servings per day
  - no consumption
  - $\leq 0.5$  servings/day
  - $0.5 \leq 1$  serving/day
  - 1 – 2 servings/day
  - more than 2 servings/day

# HCHS/SOL Motivation



# HCHS/SOL Study population

- 12,738 HCHS/SOL participants with completed FPQ
- 9 Subpopulations: field center and Hispanic/Latino background ( $n_s \geq 300$ )

	Bronx	Chicago	Miami	San Diego
Dominican	<b>1071</b>	18	54	2
Central American	164	<b>300</b>	<b>836</b>	42
Cuban	32	15	<b>1937</b>	6
Mexican	153	<b>1785</b>	28	<b>3002</b>
Puerto Rican	<b>1371</b>	<b>599</b>	65	23
South American	145	252	<b>402</b>	38
More than One	137	69	87	74

# Robust Profile Clustering (RPC)

Breaks apart global clustering assumption from mixture model  
Builds upon the local partition process (Dunson, 2009)

$$f(y_{i\cdot}|\theta) = \sum_{k=1}^K \pi_k \prod_j^p f(y_{ij}|\theta_{kj})$$

**GLOBAL**  
Variables shared with overall population

**LOCAL**  
Variables shared with subpopulation

K<sub>0</sub>: number of global clusters  
K<sub>s</sub>: number of local clusters  
p: number of exposure variables

$$f(y_{i\cdot}|\theta_0, \theta_1) = \left[ \sum_{k=1}^{K_0} \pi_k \prod_{j, G_{ij}=1}^p f(y_{ij}|\theta_{0k}) \right] \prod_{j, G_{ij}=0}^p \left[ \sum_{l=1}^{K_s} \lambda_l f(y_{ij}|\theta_{1l}^{(s)}, s_i = s) \right]$$

# RPC Components

RPC is processed through three probability models (Stephenson et al., 2020b)

- ① Global cluster membership index,  $C_i \in (1, \dots, K)$

$$\Pr(C_i = h) = \pi_h \sim Mult(\alpha + \sum_{i=1}^n 1(C_i = 1), \dots, \alpha + \sum_{i=1}^n 1(C_i = K))$$

- ② Local cluster membership index,  $L_{ij} \in (1, \dots, K)$

$$\begin{aligned}\Pr(L_{ij} = l | s_i = s) &= \lambda_l^{(s)} \\ \lambda_l^{(s)} &\sim Mult(\alpha + \sum_{i \in s, j} 1(L_{ij} = 1 | s_i = s), \dots, \sum_{i, j} 1(L_{ij} = K | s_i = s))\end{aligned}$$

- ③ Global allocation indicator,  $G_{ij}$

$$\Pr(G_{ij} = 1 | s_i = s) = \nu_j^{(s)} \sim BetaBern(a_\beta, b_\beta, \beta^{(s)})$$

# Simulation Study: Am I Global or local?

Figure 1: Case 1: Global

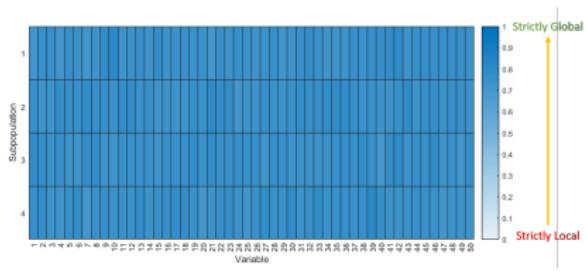


Figure 2: Case 2: Local

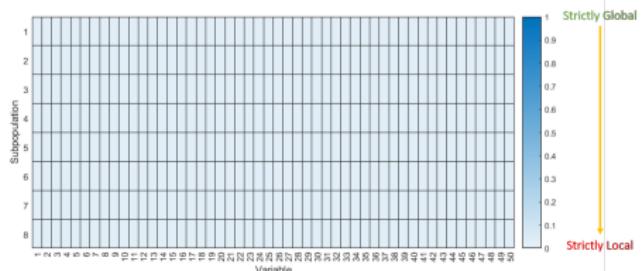
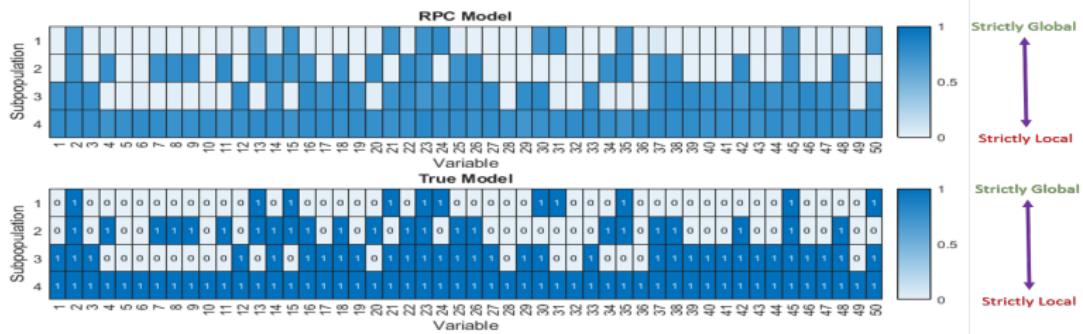


Figure 3: Case 3: Hybrid



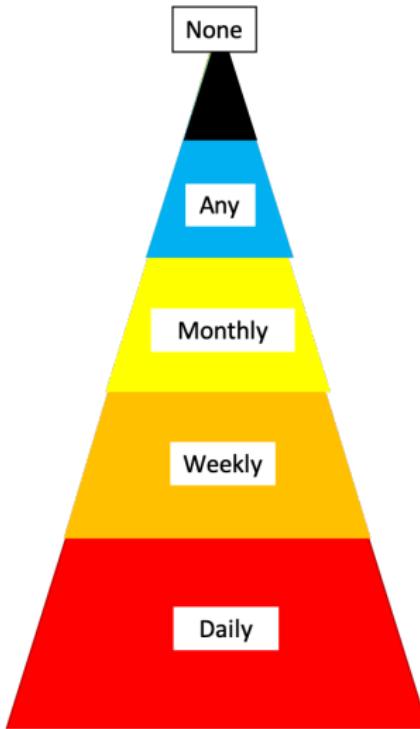
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# RPC global profiles (Stephenson et al., 2020c)

## GLOBAL PROFILE 1

- 1. Fruit pie
  - 2. Pizza (meat)
  - 3. Sweet muffins
  - 4. Fruit crisp
  - 5. Pie (not fruit)
- 
- 1. Artificial sweetener
  - 2. Corn oil
  - 3. Olive oil
  - 4. Other oil
  - 5. Canola/rapeseed oil
- 
- 1. Eggs
  - 2. Other soups
  - 3. Cheese
  - 4. Avocado
  - 5. Foods w/ added oil
- 
- 1. Nopal
  - 2. Carrots
  - 3. Broccoli
  - 4. Other fish/seafood
  - 5. Summer squash
- 
- 1. Coffee
  - 2. Cooked dried beans
  - 3. Bananas
  - 4. Fresh tomatoes
  - 5. Rice: not whole grain



## GLOBAL PROFILE 2

- 1. Fruit pie
  - 2. Diet fruit drinks
  - 3. Pie (not fruit)
  - 4. Other oil
  - 5. Meal replacement
- 
- 1. Olive oil
  - 2. Non-dairy creamer
  - 3. Canola/rapeseed oil
  - 4. Corn oil
  - 5. Pizza (meat)
- 
- 1. Cake
  - 2. Ribs
  - 3. Beef hamburger
  - 4. Potato salad
  - 5. Hot dogs
- 
- 1. Fresh tomatoes
  - 2. Bananas
  - 3. Rice: not whole grain
  - 4. Cheese
  - 5. Eggs
- 
- 1. Coffee
  - 2. Milk to coffee/tea
  - 3. Added sugar
  - 4. Foods with added oil
  - 5. Milk.

# RPC Global Profile: Frequency Distribution

		Global 1	Global 2
Bronx	Dominican	46%	<b>54%</b>
	Puerto Rican	42%	<b>58%</b>
Chicago	Central American	48%	<b>52%</b>
	Mexican	42%	<b>58%</b>
Miami	Puerto Rican	34%	<b>66%</b>
	Central American	<b>79%</b>	21%
	Cuban	<b>75%</b>	25%
San Diego	South American	<b>68%</b>	32%
	Mexican	26%	<b>74%</b>
Age	18-44 yrs	45%	<b>56%</b>
	45+ yrs	<b>55%</b>	45%
Gender	Female	48%	<b>52%</b>
	Male	50%	50%
Income	< \$30,000	<b>54%</b>	46%
	≥ \$30,000	37%	<b>63%</b>
	Not reported	<b>66%</b>	34%
Education	Less than HS	<b>55%</b>	45%
	High School/GED	47%	<b>53%</b>
	More than HS/GED	46%	<b>54%</b>

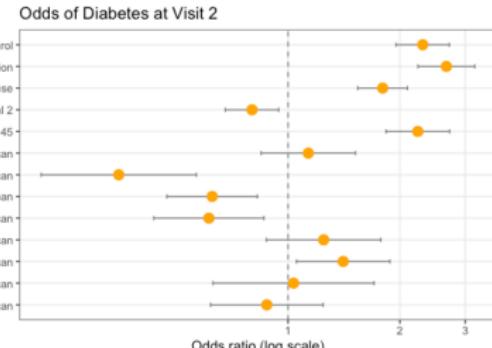
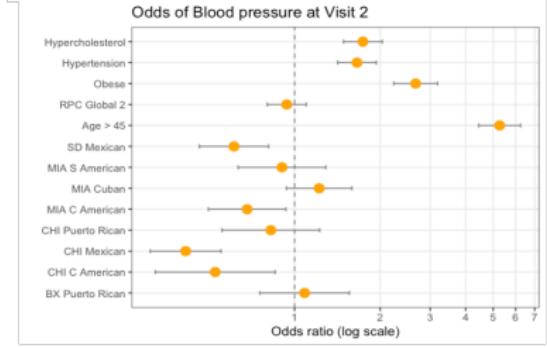
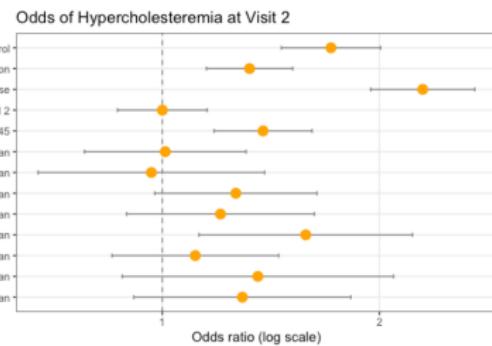
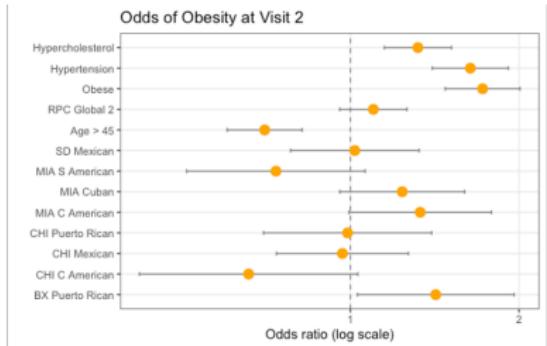
# HCHS/SOL Results: Global/Local patterns ( $\nu_j^{(s)} \geq 0.45$ )

- All: 11 global, 41 local foods
- BX participants: most global variables (Dom=37%, PR=43%)
- MIA participants: least global variables (Cub=10%,
- **Salsa**: consumed daily - Mexican (CHI,SD)
- **Nopal**: only consumed by Mexican (CHI,SD)
- **White Rice**: consumed daily - MIA Cuban and C. American
- **Milk**: daily consumed - Mexican (CHI,SD), all MIA
- **Oils**: SD-Mex not consumed; less with foods



# RPC CVD Risk factors at Visit 2

Additional Confounders: US nativity, gender, education, income, depression, alcohol, cigarette use  
Referent group: Global Profile 2; SD-Mexican background participants

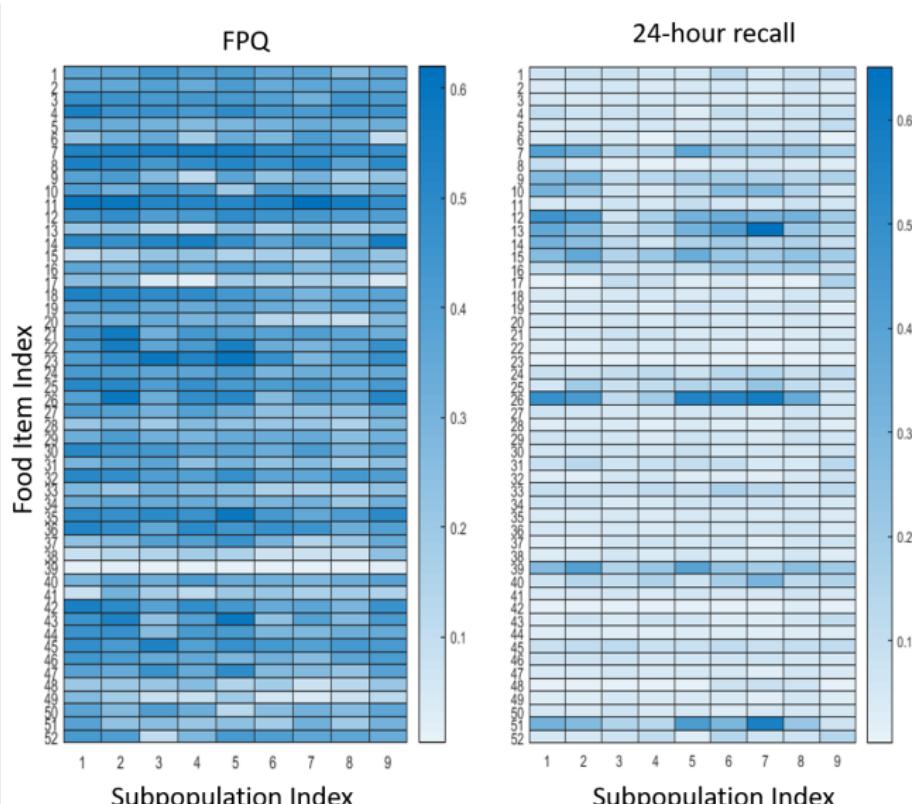


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# Application to 24HR recall: 52 food groups

Consumption sparsity drives patterns local



# Application to 24HR Recall

Challenges incorporating local profile information into regression model.

- variable selection
- fixed vs random effects

$$\xi_1 + \sum_{s=2}^S \mathbf{1}(s_i = s) \xi_s + \sum_{k=2}^{K_0} \mathbf{1}(C_i = k) \xi_{s+k} + W_i \xi_{dem} + \sum_{j,s} + \mathbf{1}(L_{ij} = l | s_i = s) b_{js}?$$

Different Approach

- Abandon a priori food clustering
- Consumption-focused clustering
- Bottom-up approach: cluster from local profiles
  - SNOB: subset nonparametric Bayesian clustering Zuanetti et al. (2019)
  - Scalable Bayesian nonparametric Clustering (Ni et al., 2020)

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# Where do we go from here?

## What we have

- Reduced model testing
- Flexible and robust interpretability
- Identify global and local patterns jointly
- User-control on rate of cluster formation

## What we still need

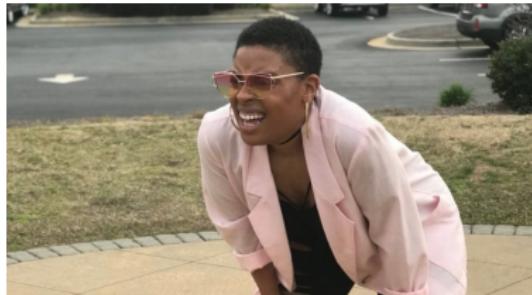
- dietary intake misreporting
- incorporation of local profile information in regression
- post-processing to remove redundancies
- probabilistic variable partitioning

# Further Directions

- Nutrient intake: Bayesian Multi-study factor analysis (in progress)
- Supervised Robust Profile Clustering (*under review*)

$$\mathcal{L}(x_i, y_i | -) = \left[ \sum_{h=1}^{K_0} \pi_h \prod_{j: G_{ij}=1}^p \prod_{r=1}^{d_j} \theta_{0jh,r}^{\mathbf{1}(x_{ij}=r)} \Phi(W_i \xi)^{y_i} [1 - \Phi(W_i \xi)]^{1-y_i} \right] \left[ \sum_{l=1}^{K_s} \lambda_l^{(s_i)} \prod_{r=1}^{d_j} (\theta_{1jl,r}^{(s_i)})^{\mathbf{1}(x_{ij}=r)} \right]$$

- Inclusion of small-sized subpopulations
- Temporal clustering under repeated measures study design
- Bayesian model-based clustering under complex survey design



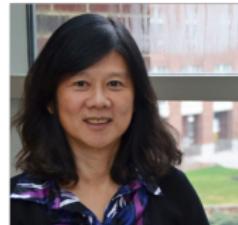
# Acknowledgements



Amy Herring



Daniela Sotres-Alvarez



Jianwen Cai



Anna-Maria Siega-Riz



Yasmin Mossavar-Rahmani



Linda Van Horn



Martha Daviglus



NHLBI: HHSN268201300001

The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) is a collaborative study supported by National Heart, Lung, and Blood Institute (NHLBI) contracts HHSN268201300001I / N01-HC-65233 to the University of North Carolina , HHSN268201300004I / N01-HC-65234 to the University of Miami, HHSN268201300002I / N01-HC-65235 to the Albert Einstein College of Medicine, HHSN268201300003I / N01-HC-65236 to the University of Illinois at Chicago (Northwestern University), and HHSN268201300005I / N01-HC- 65237 to San Diego State University. The following Institutes/Centers/Offices have contributed to the HCHS/SOL through a transfer of funds to the NHLBI: National Institute on Minority Health and Health Disparities, National Institute on Deafness and Other Communication Disorders, National Institute of Dental and Craniofacial Research, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Neurological Disorders and Stroke, and the NIH Institution-Office of Dietary Supplements.

# Any Questions?

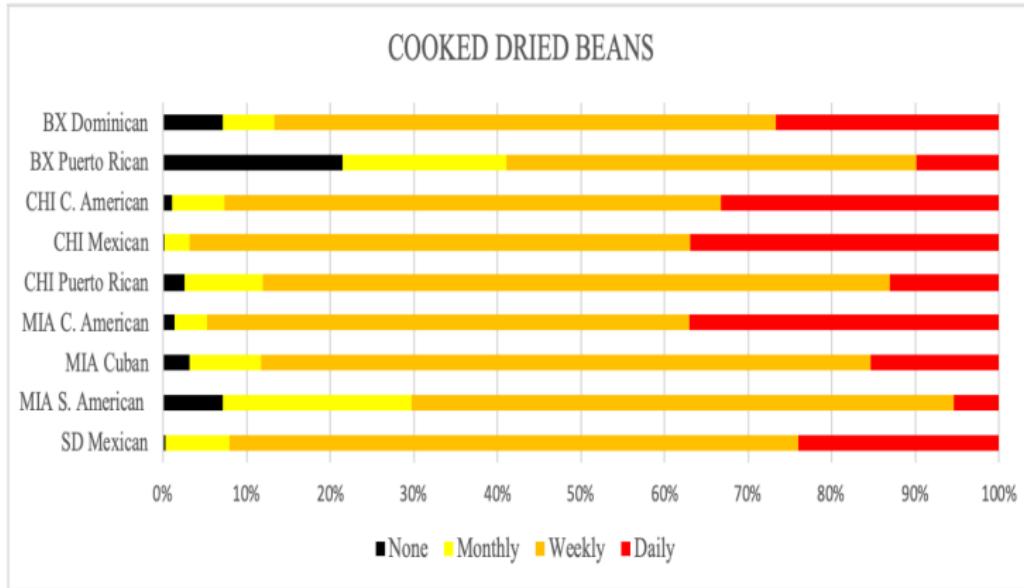


# Relevant Publications

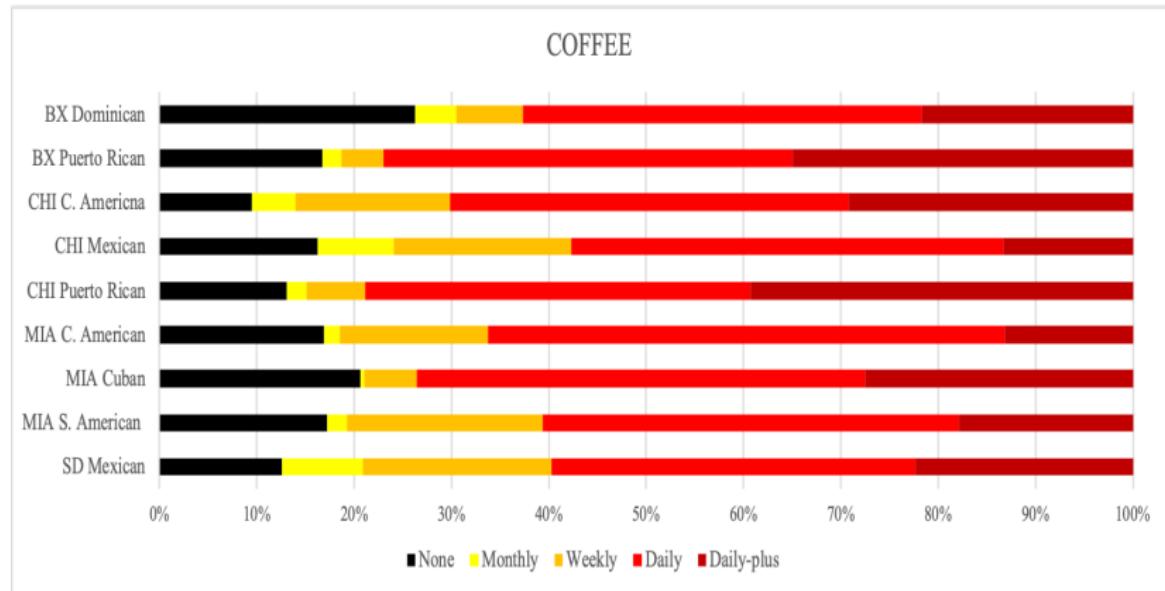
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# Extra slides

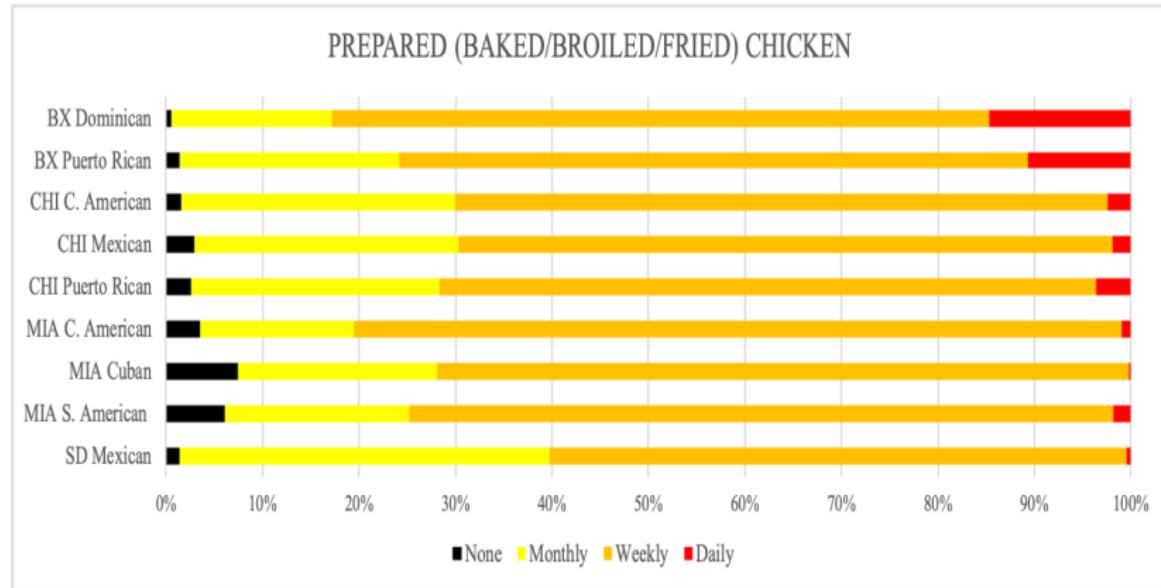
# RPC Local Profile Patterns: cooked dried beans



# RPC Local Profile Patterns: coffee



# RPC Local Profile Patterns: prepared chicken



# RPC Local Profile Patterns: corn tortillas/tacos

