Title
Anemia, Weight Status, and Fatigue Among Farmworkers in California

Journal
Journal of Occupational and Environmental Medicine, 64(8)

ISSN
1076-2752

Authors
Olivares, Leslie V
Engle-Stone, Reina
Arnold, Charles D
et al.

Publication Date
2022-08-01

DOI
10.1097/jom.0000000000002578

Peer reviewed

OPEN

Anemia, Weight Status, and Fatigue Among Farmworkers in California

A Cross-Sectional Study

Leslie V. Olivares, MS, Reina Engle-Stone, PhD, Charles D. Arnold, MS, Chelsea E. Langer, PhD, MPH, and Marc B. Schenker, MD, MPH

Objective: This study aimed to determine the prevalence of anemia and overweight/obesity and assess the relationships between hematocrit (Hct) and body mass index (BMI), and between fatigue and Hct, among a sample of farmworkers in California. **Methods:** We estimated the prevalence of anemia (using Hct), overweight/obesity (BMI ≥25 kg/m^2), and self-reported fatigue in 587 farmworkers. Multivariable linear and logistic regression models were used to examine the associations between Hct and BMI, and between fatigue and Hct. **Results:** Anemia prevalence was 3.1%, overweight/obesity prevalence was 80.7%, and 78% of workers reported fatigue at work. There was no association between Hct and BMI or between Hct and reported fatigue. Women were more likely than men to have lower Hct and higher BMI. **Conclusions:** A majority of farmworkers in this sample were overweight/obese, but anemia was uncommon. Anemia among more vulnerable subgroups of farmworkers should be explored.

Keywords: agriculture, occupational health, anemia, overweight, obesity

California produces more than one-third of the country's vegetables and two-thirds of its fruits and nuts annually.[1] In 2014, an estimated 829,300 farmworkers were employed in California.[2] Despite their essentiality, farmworkers are highly underserved and vulnerable to poor nutritional and health outcomes. Some of the challenges farmworkers face include food insecurity, lack of healthcare access, low income, and language/cultural barriers.[3–5] Much of the work around nutritional status among farmworkers in California focuses on the high prevalence of obesity and noncommunicable diseases.[6–9] In the California Agricultural Workers Health Survey (CAWHS), 81% of male and 76% of female farmworkers were reported either overweight or obese, and many suffered from additional chronic illnesses such as elevated total cholesterol, high blood pressure, and diabetes.

Little information is available on anemia prevalence and determinants among farmworkers, who may be at elevated risk for anemia. Poverty and food insecurity may lead to diets with low nutrient density.[10] Inadequate intake of certain micronutrients (particularly iron) can lead to anemia. In addition, subclinical inflammation associated with excessive adiposity and noncommunicable diseases reduces iron absorption, suggesting that obesity could also contribute to or exacerbate iron deficiency.[11,12] Inflammation may also impact erythrocyte production directly, leading to anemia independent of iron status.[12] Previous work with California farmworkers reported an anemia prevalence at 6% among men and 18% among women based on hematocrit (Hct) measurement.[13] Among farmworkers living on the US-Mexico border, a 23.2% prevalence based on hemoglobin (Hgb) has been observed.[14] However, there is little information on anemia prevalence and determinants among farmworkers.

Anemia is associated with reduced physical work capacity[15–17] and may have health and economic impacts for farmworkers, particularly those paid by piece rate. Anemia compromises oxygen-carrying capacity,[18] which can cause weakness, fatigue, and difficulty to concentrate.[16] This can exacerbate the effects of other occupational health hazards such as risk of injury or heat illness. Farm work involves high occupational activity,[19] and production of labor-intensive commodities, including fruits and vegetables, is increasing.[20] To assess whether anemia among farmworkers warrants greater attention and to develop appropriate interventions, we must address gaps in knowledge on prevalence, associated factors, and potential consequences for farmworkers. We aimed to determine the prevalence of anemia and overweight/obesity, assess the relationship between Hct and body mass index (BMI), and assess the relationship between fatigue and Hct among a sample of farmworkers in California. In addition, we assessed factors associated with Hct, anemia, BMI, and obesity.

METHODS

We used data from the California Heat Illness Prevention Study (CHIPS),[21] a cross-sectional study for which data were collected in the summer (June to October) of 2014 and 2015. A convenience sample of 587 farmworkers was recruited from 30 farms throughout California through farm managers and farm labor contractors. Written consent of workers was obtained a day before subsequent data collection. Data collection took place on farms at the participants' work site. Bilingual interviewers administered questionnaires, took anthropometric measures, and collected capillary blood. Additional details of the study methods have been previously described.[21] Study participant procedures were approved by the University of California, Davis, Institutional Review Board. The STROBE cross-sectional reporting guidelines were used.[22]

Eligibility

To be eligible, farmworkers needed to work outdoors for a full shift (varying from 5 to 12 hours), including nursery workers who only worked outside or landscapers in rural settings. Participants needed to self-identify as Latino/a, speak Spanish or English, and have a normal body temperature at start of their workshift (temperature <37.5°C, assessed using a tympanic ear thermometer). Workers were not eligible if their work entailed frequent driving; they were younger than 18 years, pregnant, unable to swallow large pills (a requirement for body temperature monitoring, for the primary study aims), or experiencing

From the Department of Nutrition, University of California, Davis, Davis, California (Ms Olivares, Dr Engle-Stone, Mr Arnold); Institute for Global Nutrition, University of California, Davis, Davis, California (Dr Engle-Stone); Center for Health and the Environment, University of California, Davis, Davis, California (Dr Langer); and Department of Public Health Sciences, University of California, Davis, Davis, California (Dr Schenker).

Ethical Considerations: All study procedures were reviewed and approved by the University of California, Davis Institutional Review Board (protocol number 288691).

Funding Sources: The California Heat Illness Prevention Study was supported by grant agreement numbers R01OH010243 and U54OH007550 from the Centers for Disease Control and Prevention National Institute for Occupational Safety and Health. The secondary data analysis was supported by the USDA National Institute of Food and Agriculture Hatch Project 1013897.

Conflict of Interest: None declared.

Address correspondence to: Reina Engle-Stone, PhD, Department of Nutrition, Institute for Global Nutrition University of California, Davis 1 Shields Ave, Davis, CA 95616 (renglestone@ucdavis.edu).

DOI: 10.1097/JOM.0000000000002578

gastrointestinal upset at the start of the workshift; they had an implanted electromedical device; or they recently underwent stomach surgery.

Interviews

A questionnaire was administered before the participants' shift began, and a second questionnaire was administered at the end of their shift. Demographic information, including age, sex, and housing, was collected in the preshift questionnaire, whereas most other information such as cultural background, education, substance use, employment details, and fatigue was collected during the postshift questionnaire. To assess fatigue, participants were asked how fatigued they normally feel at work and could indicate "Not at all," "A little tired," "Very tired," "So tired I would like to rest, but do not do so," or "So tired I take extra rests."

Anthropometry

Anthropometric measurements were taken in the morning using a Seca™ model 213 stadiometer (Seca GMBH & Co. KG, Hamburg, Germany) for height and a Seca™ Model 874 m scale (Seca GMBH & Co. KG) for weight. Height was measured twice in the morning without shoes. Workers were weighed twice in the morning and twice at the end of their workshift without shoes wearing only a base layer of clothing. An average of the 2 morning measurements was used for this analysis. Weight scales were placed on a board and leveled before weighing.

Blood Samples

Capillary blood was collected in the morning and at the end of the workshift. For this analysis, morning samples were used. The sample (~95 μL) was analyzed immediately after collection using a battery operated i-STAT™ analyzer (Abbot Point of Care Inc., Princeton, NJ). To maintain the optimum instrument temperature (16°C–30°C) and to protect from dust or other materials, samples were analyzed in a diesel-powered car. Chem8+ panels were used to measure Hct and blood solutes (sodium, potassium, glucose, blood urea nitrogen) used to calculate serum osmolality based on the Wallach equation.[23] Anemia was defined as Hct <39% for men and <36% for women based on World Health Organization International Nutritional Anemia Consultative Group guidelines.[24] Dehydration was defined as serum osmolality >295 mOsm based on the standard range of euhydration.[25]

Statistical Analysis

Descriptive statistics were calculated for participants overall and stratified by sex. Primary outcomes included Hct with BMI as the main predictor, and reported fatigue with Hct as the main predictor. Responses for reported fatigue were dichotomized to represent "not at all tired" and "tired (to any extent)" (not at all tired = 0, tired = 1). Secondary outcomes included anemia (without anemia = 0, with anemia = 1: Hct <39% for men and < 36% for women) and obesity (without obesity = 0, with obesity = 1: BMI ≥30 kg/m^2) for which exploratory analysis was conducted to identify significant predictors.

With n = 587, we estimated that we could detect a correlation of 0.12 between Hct and BMI. The question on fatigue was added while the study was ongoing, resulting in a smaller sample size for this variable (n = 282 with sufficient data). With this sample size, we could detect a mean difference of 0.41 SD Hct between those reporting fatigue and those not.

We applied linear or logistic regression for continuous and dichotomous outcomes, respectively. For each, we assessed relationships between each outcome and predictor of interest in a series of models, moving from unadjusted to minimally and fully adjusted models. Unadjusted models included the outcome and main predictor of interest. Minimally adjusted models controlled for age and sex. Fully adjusted models additionally controlled for covariates that were associated with the outcome in bivariate models ($P < 0.10$). Multivariable models were assessed for collinearity between all predictors. Effect modification of the predictor of interest by sex and age was tested in minimally adjusted models. We specified a priori that significant effect modification in minimally adjusted models would be retained in fully adjusted models, although no effect modification was found in models examining the primary objectives.

Exploratory analyses were conducted to examine factors potentially associated with Hct, anemia, BMI, and obesity. We constructed multivariable models using a block forward selection approach. The variable blocks were defined based on proximity to the outcome in the hypothesized causal framework for each outcome and were grouped as individual-level characteristics (block 1: age and sex), behavioral characteristics (block 2: alcohol consumption and smoking), and underlying characteristics (block 3: additional demographic, occupational, and biological factors). Age and sex (block 1, individual characteristics) were included in all models. At each subsequent stage, only predictors associated with the outcome ($P < 0.10$) continued to the next level. Multivariable models were assessed for collinearity between all predictors. Effect modification by sex was tested for each variable entered into the model; interaction terms associated with the outcome at a level of $P < 0.10$ were retained in subsequent steps. In the case of significant interaction, stratified results are presented.

Categories that contained less than 15 observations were collapsed or removed from the model. For example, ethnicity was not included in models because only 3 participants in the study did not self-identify as Latino or indigenous and only 10 self-identified as indigenous. Categorical predictors in models with a categorical outcome where there were zero or too few observations in a single cell for analysis to be possible were not considered or removed from the model. All analyses were conducted using SAS 9.4 (SAS Institute, Inc, Cary, NC).

RESULTS

Of the 587 participants, 66.3% were male. On average, participants were 39 years old and had worked in agriculture for 14 years (Table 1). Approximately half (53.7%) had an annual family income of ~$10,000 to $30,000, with 9.2% earning $5000 or less per year. Anemia was observed in 18 of 579 workers (3.1%) for whom Hct values were available (Table 1). Prevalence of anemia was significantly higher among women compared with men (6.2% vs 1.6%; $P = 0.003$). A substantial majority (80.7%) of workers were either overweight or obese, and prevalence of overweight and obesity combined was greater among women compared with men (86.9% vs 77.7%; $P = 0.007$). When asked about fatigue, 78% of workers indicated that they generally felt tired to some extent at work (including those who reported any level of fatigue), with no difference among men versus women ($P = 0.67$).

Body mass index was not associated with Hct in unadjusted or minimally adjusted models (Table 2). In the fully adjusted regression model, there was no significant association between Hct and BMI, but significant ($P < 0.10$) covariates included age, sex, primary language, income, and serum osmolality.

Hematocrit was not associated with reported fatigue in unadjusted or minimally adjusted models (Table 3); sex and age were also not associated with reported fatigue. The fully adjusted models were identical to the minimally adjusted model, as no additional covariates met the criteria to be included in the final model. This result was unchanged in a sensitivity analysis including serum osmolality as a methodological confounder (data not shown).

In the exploratory analysis of factors associated with Hct, the final linear regression model suggested that younger age, male sex, speaking English as a primary language, and greater serum osmolality were associated with greater Hct (Table 4); income was associated with Hct ($P = 0.07$) but without an apparent pattern. Fewer factors were associated with anemia: individuals without anemia were more likely to be younger, be male, and have higher serum osmolality (Table 6).

Models exploring factors associated with BMI were conducted for the overall sample (Table 4) and stratified by sex (Table 5) because

TABLE 1. Demographic and Health Characteristics of Participating Farmworkers, Overall and by Sex

	Male (n = 389)		Female (n = 198)		All (n = 587)	
	Mean (SD), Range, or *n* (%)	*n*	Mean (SD), Range, or *n* (%)	*n*	Mean (SD), Range, or *n* (%)	*n*
Age, yr	38.7 (12.7), 18–82	389	38.7 (10.8), 18–70	198	38.7 (12.1), 18–82	587
Ethnicity		387		197		584
Latina/o	374 (96.6)		196 (99.5)		570 (97.6)	
Indigenous	10 (2.6)		1 (0.5)		11 (1.9)	
Other	3 (0.8)		0 (0)		3 (0.5)	
Country born		389		198		587
United States	43 (11.1)		5 (2.5)		48 (8.2)	
Mexico	334 (85.9)		185 (93.4)		519 (88.4)	
Central America	12 (3.1)		8 (4.0)		20 (3.4)	
Primary language		389		198		587
English	24 (6.2)		7 (3.5)		31 (5.3)	
Spanish	350 (90.0)		184 (92.9)		534 (91.0)	
Other/indigenous	15 (3.9)		7 (3.5)		22 (3.8)	
Education level completed		197		117		314
None	13 (6.6)		3 (2.6)		16 (5.1)	
Grades 1–6	79 (40.1)		73 (62.4)		152 (48.4)	
Grades 7–11	53 (26.9)		28 (23.9)		81 (25.8)	
High school graduate or more	52 (26.4)		13 (11.1)		65 (20.7)	
Years in school	7.6 (3.9), 0–15	197	6.6 (3.2), 0–13	117	7.3 (3.7), 0–15	314
Housing		389		198		587
House	236 (60.7)		115 (58.1)		351 (59.8)	
Apartment	99 (25.5)		67 (33.8)		166 (28.3)	
Mobile home/trailer	48 (12.3)		14 (7.1)		62 (10.6)	
Other	6 (1.5)		2 (1.0)		8 (1.4)	
Years in agriculture	15.9 (12.7), 0–66	387	11.1 (9.5), 0–47	198	14.3 (11.9), 0–66	585
Paid by*		389		198		587
Piece	90 (23.1)		37 (18.7)		127 (21.6)	
Hourly/salary	299 (76.9)		161 (81.3)		460 (78.4)	
Family income/yr		374		190		564
$0–$5000	31 (8.3)		21 (11.1)		52 (9.2)	
$5001–$10,000	39 (10.4)		36 (19.0)		75 (13.3)	
$10,001–$20,000	97 (25.9)		57 (30.0)		154 (27.3)	
$20,001–$30,000	110 (29.4)		39 (20.5)		149 (26.4)	
$30,001–$40,000	72 (19.3)		24 (12.6)		96 (17.0)	
> $40,000	25 (6.7)		13 (6.8)		38 (6.7)	
Serum osmolality, mOsm	284.9 (4.6), 270.2–311.0	377	283.5 (4.5), 260.8–301.2	186	284.4 (4.6), 260.8–311.0	563
Dehydrated before work† (yes)	9 (2.4)	377	2 (1.1)	186	11 (2.0)	563
Alcohol consumption		389		198		587
Never drinks	61 (15.7)		107 (54.0)		168 (28.6)	
Former drinker	49 (12.6)		22 (11.1)		71 (12.1)	
Current drinker	279 (71.7)		69 (34.9)		348 (59.3)	
No. alcoholic beverages/mo (current drinkers)	37.0 (52.3), 1–360	275	5.8 (10.4), 1–54	67	30.9 (48.7), 1–360	342
Degree of alcohol consumption		336		174		510
Never, 0 drinks/mo	61 (18.2)		107 (61.5)		168 (32.9)	
Light, 1–36 drinks/mo	193 (57.4)		64 (36.8)		257 (50.4)	
Moderate, 37–66 drinks/mo	43 (12.8)		3 (1.7)		46 (9.0)	
Heavy, >66 drinks/mo	39 (11.6)				39 (7.7)	
Smoking status		389		198		587
Never smoked	213 (54.8)		182 (91.9)		395 (67.3)	
Former smoker	89 (22.9)		14 (7.1)		103 (17.6)	
Current smoker	87 (22.4)		2 (1.0)		89 (15.2)	
Average no. cigarettes smoked/d (current and former)	6.9 (7.6), 0.6–40.0	161	2.8 (2.6), 1–10	12	6.6 (7.5), 0.6–40	173
BMI, kg/m^2	28.8 (4.6), 18.9–47.6	389	29.7 (4.6), 20.7–50.2	198	29.1 (4.6), 18.9–50.2	587
Weight status		389		198		587
Normal, BMI <25.0 kg/m^2	87 (22.4)		26 (13.1)		113 (19.3)	
Overweight, BMI 25.0–29.9 kg/m^2	161 (41.4)		91 (46.0)		252 (42.9)	
Obese, BMI ≥30.0 kg/m^2	141 (36.3)		81 (40.9)		222 (37.8)	
Hct, %	46.0 (3.3), 32–55	384	40.5 (3.0), 34–48	195	44.2 (4.2), 32–55	579
Anemia (yes)‡	6 (1.6)	384	12 (6.2)	195	18 (3.1)	579
General fatigue at work§		194		93		287
Not at all tired	44 (22.7)		19 (20.4)		63 (22.0)	
A little tired	133 (68.6)		70 (75.3)		203 (70.7)	
Very tired +	17 (8.8)		4 (4.3)		21 (7.3)	

BMI, body mass index.

*Paid by: category "Piece" includes anyone paid by piece rate alone or any combination of payment with piece rate.

†Dehydration cutoff: dehydrated if serum osmolality >295 mOsm.

‡Anemia cutoff: anemic if Hct <39% for men and <36% for women.

§General fatigue at work: category "Very tired +" includes participants that indicated they were "very tired," "tired enough to desire more breaks but do not take them," or "tired enough to actually take more breaks."

TABLE 2. Multiple Linear Regression of the Association Between Hct and BMI

	Unadjusted Model (n = 579)			Age- and Sex-Adjusted Model (n = 579)			Model Incorporating Additional Factors (n = 471)		
	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
BMI, kg/m^2	−0.03	0.04	0.35	0.02	0.03	0.48	−0.005	0.03	0.87
Sex (female)				−5.72	0.30	<0.0001	−5.29	0.36	<0.0001
Age, yr				−0.05	0.01	<0.0001	−0.07	0.01	<0.0001
Country born									0.13
United States (reference)							—	—	—
Mexico							0.64	0.58	0.28
Central America							2.07	1.02	0.04
Primary language									0.02
English							1.69	0.70	0.02
Spanish (reference)							—	—	—
Other/indigenous							−1.24	0.88	0.16
Education level completed									0.12
None (reference)							—	—	—
1–6							−1.85	0.91	0.04
7–11							−1.31	0.95	0.17
High school graduate or more							−1.84	0.99	0.06
Don't know							−1.18	0.90	0.19
Family income/yr									0.03
\$0–\$5000							0.62	0.71	0.38
\$5001–\$10,000							−1.14	0.68	0.09
\$10,001–\$20,000							−0.81	0.61	0.18
\$20,001–\$30,000							−0.62	0.61	0.31
\$30,001–\$40,000							−0.10	0.65	0.88
> \$40,000 (reference)							—	—	—
Serum osmolality							0.13	0.03	<0.0001
Current smoker (no)							−0.40	0.40	0.33
Degree of alcohol consumption									0.94
Never, 0 drinks/mo (reference)							—	—	—
Light, 1–36 drinks/mo							−0.14	0.34	0.68
Moderate, 37–66 drinks/mo							−0.19	0.56	0.74
Heavy, >66 drinks/mo							0.13	0.60	0.83

Covariates with a significant association with the outcome in bivariate analysis ($P < 0.10$) were kept in the final model. Variables tested but not significant ($P \geq 0.10$) included housing, years in agriculture, and type of pay.

BMI, body mass index; Hct, hematocrit.

of an interaction between sex and primary language. The overall final linear regression model of factors associated with BMI included sex, age, current smoking status, income, years in agriculture, primary language, and the interaction between sex and primary language. Among men, greater BMI was associated with current nonsmoking (never and former), years in agriculture, and speaking Spanish (vs other/indigenous languages) as a primary language. Among women, BMI was greater among women who spoke English as a primary language (vs Spanish), but associations with other factors were not statistically significant.

The final logistic regression model of factors associated with obesity included age, sex, serum osmolality, and primary language (Table 6). In this model, obesity was less common among individuals with reported primary language of other/indigenous, compared with Spanish; no other variables were significantly associated. An interaction between primary language and sex was also significant but not included in the model because of small numbers (<5 observations among certain combinations of categories). For example, there was only one woman who was classified as not obese and indicated English as her primary language.

DISCUSSION

Anemia prevalence was low in this sample, but differences by sex did exist (1.6% of men, 6.2% of women). These results are lower than previous findings from the CAWHS, which reported prevalence

TABLE 3. Logistic Regression of the Association Between "No Fatigue" and Hct

	Unadjusted Model (n = 282)			Age- and Sex-Adjusted Model (n = 282)		
	OR	95% CI	P	OR	95% CI	P
Hct	1.03	0.96–1.11	0.40	1.02	0.93–1.12	0.64
Sex (female)				0.91	0.40–2.08	0.83
Age				1.00	0.97–1.02	0.69

No other variables examined were significantly associated with the outcome ($P < 0.10$) in bivariate analyses. Therefore, the fully adjusted model was identical to the age- and sex-adjusted model. Variables tested but not significant ($P \geq 0.10$) included country of birth, primary language, education level completed, housing, years in agriculture, type of pay, family income, serum osmolality, alcohol consumption, current smoking, and body mass index.

CI, confidence interval; Hct, hematocrit; OR, odds ratio.

TABLE 4. Factors Associated With BMI and Hct Concentration Based on Linear Regression

	Age- and Sex-Adjusted Model			Model Incorporating Behavioral Characteristics			Model Incorporating Underlying Characteristics (Fully Adjusted)		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BMI		n = 587			n = 587			n = 562	
Age	0.03	0.02	0.05	0.03	0.02	0.05	0.004	0.02	0.86
Sex (female)	0.93	0.42	0.03	0.72	0.44	0.10	0.58	0.46	0.002
Current smoker (no)				−0.96	0.56	0.08	1.20	0.56	0.03
Primary language									0.001
English							−1.63	1.01	0.11
Spanish (reference)							—	—	—
Other/indigenous							−2.98	1.25	0.02
Family income/yr									0.65
$0–$5000							−0.83	0.99	0.40
$5001–$10,000							−0.46	0.91	0.61
$10,001–$20,000							−0.26	0.83	0.75
$20,001–$30,000							−0.33	0.83	0.69
$30,001–$40,000							0.47	0.88	0.59
>$40,000 (reference)							—	—	—
Years in agriculture							0.05	0.02	0.04
Primary language interaction with sex									0.0006
English × female							8.24	2.14	0.0001
Spanish × female (reference)							—	—	—
Other/indigenous × female							−0.34	2.26	0.88
Hct, %		n = 579			n = 579			n = 540	
Age	−0.05	0.01	<0.0001	−0.05	0.01	<0.0001	−0.06	0.01	<0.0001
Sex (female)	−5.70	0.30	<0.0001	−5.70	0.30	<0.0001	−5.41	0.30	<0.0001
Primary language									0.04
English							1.32	0.60	0.03
Spanish (reference)							—	—	—
Other/indigenous							−0.93	0.74	0.20
Family income/yr									0.07
$0–$5000							0.97	0.67	0.14
$5001–$10,000							−0.46	0.61	0.45
$10,001–$20,000							−0.30	0.55	0.59
$20,001–$30,000							−0.09	0.56	0.87
$30,001–$40,000							0.48	0.60	0.42
> $40,000 (reference)							—	—	—
Serum osmolality							0.12	0.03	<0.0001

Covariates with a significant association with the outcome in the full model ($P < 0.10$) were kept in the final model. Variables tested but not significant ($P \geq 0.10$) included the following: BMI behavioral characteristics model (alcohol consumption), BMI underlying characteristics model (country born, education level completed, housing, type of pay, serum osmolality, fatigue), Hct behavioral characteristics model (current smoking status, alcohol consumption), and Hct underlying characteristics model (country of birth, education level completed, housing, years in agriculture, type of pay).

BMI, body mass index; Hct, hematocrit.

of anemia at 6% for men and 18% for women.[13] Prevalence of overweight and obesity in this population was high (77.7% of male workers and 86.9% of female workers). This is consistent with a previous survey in California, which reported rates of overweight or obese as high as 81% for male workers and 76% of female workers.[13]

Findings on anemia prevalence may be explained in part by the "healthy worker effect," as it is less likely for those who are chronically or severely ill to be a part of the workforce,[26] and possible sampling bias. For instance, participants of the CHIPS study were an actively working population recruited at their worksite, whereas participants of the CAWHS were recruited at their homes. Thus, even if participants of both studies were farmworkers, differences in study recruitment may result in samples of participants more likely to differ by working conditions, employment status, and physical fitness.

The lack of relationship between Hct and BMI is inconsistent with what we would expect based on the biological relationships between excess adiposity, iron absorption, and anemia risk.[12] We hypothesized that higher BMI would be associated with lower Hct due to the effects of inflammation on iron absorption and erythropoiesis. The null findings do not negate the possibility that such a relationship exists, but they suggest that these metabolic relationships may not have a meaningful effect on anemia prevalence in our sample. Despite evidence from studies of obesity and iron metabolism, results from population-based studies examining this relationship have been less clear. For example, a 2012 study that examined the coexistence of overweight/obesity with anemia among women in Mexico observed a significantly higher prevalence of this double burden than would have been expected assuming that these conditions occurred independently (7.6% vs 7.2%),[27] suggesting that overweight/obese women were more likely to have anemia compared with women with normal BMI. However, the authors concluded that this magnitude of association was not meaningful.[27] We also recognize that BMI is not an accurate measure of adiposity; information on adiposity and fat distribution may give more insight into the relationship. For example, a study in Sweden published in 1991 looked at types of obesity among women and found that women with android obesity had Hct and red blood cell count values that were significantly higher than women with gynoid obesity.[28]

In our exploratory analysis, Hct was greater among younger adults, men, those who primarily spoke English, or those who had higher serum osmolality. It is not surprising for men and younger adults to have higher Hct because men are generally at less risk for

TABLE 5. Fully Adjusted Models of Factors Associated With BMI Based on Linear Regression Stratified by Sex

	Male (n = 372)			Female (n = 190)		
BMI	**Estimate**	**SE**	***P***	**Estimate**	**SE**	***P***
Age	−0.01	0.03	0.71	0.02	0.04	0.53
Sex (female)	—	—	—	—	—	—
Current smoker (no)	1.21	0.57	0.03	2.28	3.32	0.49
Primary language			0.03			0.0004
English	−1.61	1.02	0.11	6.94	1.91	0.0004
Spanish (reference)	—	—	—	—	—	—
Other/indigenous	−2.77	1.27	0.03	−3.23	1.98	0.10
Family income/yr			0.33			0.83
$0–$5000	−0.87	1.25	0.49	−0.50	1.64	0.76
$5001–$10,000	−1.17	1.17	0.32	0.21	1.48	0.89
$10,001–$20,000	−0.31	1.03	0.76	−0.36	1.39	0.80
$20,001–$30,000	−0.01	1.02	0.99	−1.27	1.46	0.39
$30,001–$40,000	0.83	1.08	0.44	−0.34	1.56	0.83
> $40,000 (reference)	—	—	—	—	—	—
Years in agriculture	0.04	0.03	0.10	0.07	0.04	0.12

Covariates were selected based on the unstratified fully adjusted model incorporating underlying characteristics for BMI (Table 4) without the interaction term.

BMI, body mass index.

developing anemia[29] and elderly people are often at higher risk.[30] However, in this population, it is possible that the association with age could reflect anemia of chronic disease among older workers. The positive association between Hct and serum osmolality is expected given that lower hydration can increase Hct because of decreased plasma volume. This could theoretically mask anemia diagnosis; however, this is not likely in our sample considering only 2% of workers were classified as dehydrated. Nevertheless, hydration may be an important methodological variable to consider in studies of anemia. The observation that participants who primarily speak English had higher Hct compared with participants who primarily spoke Spanish is consistent with previous work showing that US-born workers are less likely to have poor work conditions.[31] However, only 5.3% of workers reported English as their primary language, making it difficult to draw definite conclusions. Similarly, we observed a marginal association ($P = 0.07$) between income level and higher Hct, but there was no clear trend of increasing/decreasing Hct across levels of income.

Overweight and obesity have been recognized as a major health concern among farmworkers in California.[13] Our exploratory analyses suggested that BMI was higher among men who were nonsmokers, did not primarily speak a language categorized as "other/indigenous" in comparison with those who primarily spoke Spanish, or worked more years in agriculture. However, prevalence of overweight and obesity combined was significantly higher among women compared with men (86.9% vs 77.7%, $P = 0.007$), and among women, BMI was higher among those who primarily spoke English compared with those who primarily spoke Spanish. This finding is not consistent with the CAWHS results, in which prevalence of overweight and obesity combined was higher among men (81% vs 76%).[13] For comparison, the 2013–2014 National Health and Nutrition Examination Survey found that, although combined prevalence of overweight/obesity was higher among all men (73.7% vs 66.9%), obesity and extreme obesity (BMI ≥40 kg/m^2) alone were higher among women.[32]

In this sample, men who did not currently smoke had higher BMI compared with men who currently smoked, although drawing conclusions is difficult considering that not many workers currently smoked (15.2%) and the average number of cigarettes smoked per day by current and former smokers was low (<7 cigarettes). This is consistent with previous work that has described the general low prevalence of smoking among Latino farmworkers.[33] Nevertheless, lower body weight among smokers is consistent with what has been observed in previous work looking at smoking and weight.[34] An association between smoking status and BMI could be related to the effects of smoking on metabolism and appetite that have been associated with tobacco use in previous work.[34] For men who primarily spoke English or Spanish and worked more years in agriculture, having higher BMI could indicate an association between acculturation and BMI; however, there are many other factors to consider such as immigration status, time in the US, and country of education. In addition, years in agriculture for this study did not distinguish between years worked in the United States versus other countries. Previous work on acculturation among farmworkers found that being born in Mexico or Central America and having lived in the United States for a longer period were associated with being more likely to consume ≥5 servings of fruits/vegetables per day, whereas higher acculturation level, US education, and having a child at home were associated with being less likely to consume ≤35% of calories from fat.[35] However, there were very few participants who were not "low acculturated" in that study.[35] Considering the homogeneity among the participants in the current study with regard to some of the demographic

TABLE 6. Factors Associated With BMI <30 kg/m^2 and Nonanemic Status Based on Linear and Logistic Regression

	Age- and Sex-Adjusted Model			Model Incorporating Behavioral Characteristics			Model Incorporating Underlying Characteristics		
	OR	**95% CI**	***P***	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***
Not obese		**n = 587**			**n = 587**			**n = 563**	
Age	0.10	0.98–1.01	0.58	1.00	0.98–1.01	0.58	1.00	0.98–1.01	0.66
Sex (female)	0.82	0.58–1.17	0.27	0.82	0.58–1.17	0.27	0.92	0.64–1.34	0.67
Serum osmolality							1.01	0.98–1.05	0.49
Primary language									0.09
English							1.07	0.50–2.31	0.86
Spanish (reference)							—	—	—
Other/indigenous							3.99	1.16–13.71	0.03
Not anemic		**n = 579**			**n = 579**			**n = 563**	
Age	0.97	0.93–1.01	0.10	0.97	0.93–1.01	0.10	0.94	0.89–0.98	0.01
Sex (female)	0.25	0.09–0.69	0.01	0.25	0.09–0.69	0.01	0.24	0.07–0.75	0.01
Serum osmolality							1.18	1.06–1.32	0.003

Covariates with a significant association with the outcome in the full model ($P < 0.10$) were kept in the final model. Variables tested but not significant ($P \geq 0.10$) included the following: obesity behavioral characteristics model (current smoking status, alcohol consumption), obesity underlying characteristics model (country of birth, education level completed, housing, years in agriculture, type of pay, family income, fatigue; primary language interaction with sex was significant but not included in the final model because of very small cell size), anemia behavioral characteristics model (current smoking status, alcohol consumption), and anemia underlying characteristics model (country of birth, primary language, education level completed, housing, years in agriculture, type of pay, family income).

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

information, there is a possibility that this may also be the case with acculturation among our sample of workers.

Lastly, we did not find an association between Hct and fatigue. This is unexpected based on the physiological consequences of anemia, including reduced oxygen-carrying capacity and reducing capacity for physical work.[15,16] For example, a study of female tea estate workers in Sri Lanka reported a significant association between iron deficiency anemia and reduced physical work capacity.[17] The lack of association in this study may be related to the low prevalence of anemia in this sample and the low sample size for detecting a relationship with a binary outcome; of the 18 farmworkers with anemia, 8 reported they were "tired (to any extent)." Thus, there remains some uncertainty regarding how anemia may affect work performance and earnings among farmworkers in settings where anemia prevalence is higher, or degree of anemia is more severe. It is also important to note that previous work on this sample showed that farmworkers generally operated at fairly low activity levels (lower than expected/previously assumed).[36] At lower activity levels, it may be less likely for the less severe impacts on work capacity from fatigue to be noticed and therefore less likely to be reported.

A strength of this study was its large sample size (n = 587), for which data were collected on farms that were located in the Central Valley and the Imperial Valley, both of which are major regions of crop production in California. The sample was well balanced by sex allowing us to disaggregate results for men and women. The sample demographics were also comparable with that of the 2013–2014 National Agricultural Workers Survey.[21] Coincidentally, data on serum osmolality were collected, which allowed us to control for this methodological variable when examining Hct.

A limitation of this study was using a convenience sample permitted to participate by employers. More vulnerable workers in facilities that would not welcome researchers may be at higher risk for negative health outcomes from work conditions. The 2008–2012 National Agricultural Workers Survey reported that farmworkers who were both undocumented and indigenous did work that was more labor intensive and less secure, and were more likely to be paid by piece rate compared with undocumented Latino workers, whereas US-born workers had more job security, were paid more per hour, and had less labor-intensive work.[31] Only 1.9% of workers in this study identified as indigenous, and most were not paid by piecework or any combination of it (78.4%). Previous work throughout California suggested that indigenous workers face greater disparities in food security, legal status, education, language barriers, and healthcare access.[3,5] These results may underestimate anemia prevalence by not adequately capturing more vulnerable farmworkers.

Hemoglobin is the preferred method for assessing anemia,[37] but for this study, only Hct was measured. Smoking can also impact anemia assessment.[38] We were mainly interested in recent smoking status (currently smoke or quit recently) because measures of hematological indicators in former smokers who quit within 2 years become similar to that of never smokers[39]; however, we did not have information on how long ago former smokers quit. In addition, only 15.2% of workers in this sample were smokers, making it difficult to identify associations. Because few workers were anemic, the statistical power to identify factors associated with anemia was limited. In addition, relevant data such as diet, food insecurity, supplement use, or biomarkers of iron status or inflammation were not available. Homogeneity of our sample due to a high prevalence of overweight/obesity further limits statistical power in finding relationships between Hct and BMI. It is possible that BMI-related changes in iron status were too small to detect using Hct or Hgb.

There are various factors aside from Hct that can impact fatigue among farmworkers for which we lacked data, such as diabetes, depression, pesticide exposure, and heat.[40–43] Previous work from the CHIPS study observed that level of physical activity was associated with environmental temperature, age, amount of tasks, certain types of tasks, and payment by piece rate (men only).[36] However, level of physical activity is not synonymous with level of fatigue. In addition, fatigue was reported right after worker's shifts, which may influence responses based on that day. Previous work with farmworkers also found that fatigue was significantly predicted by sex, pain, hours of sleep, and job demands.[44] Furthermore, the question on fatigue was added later, resulting in a smaller sample size and limiting statistical power. Although we did not identify a significant association between Hct and fatigue, this is an area of interest for both the health and safety of workers whose income depends on their physical work capacity and employers relying on worker productivity.

Conclusions

This analysis of a large sample of farmworkers recruited on farms in California confirmed the high prevalence of overweight/obesity among California farmworkers and provided new information on prevalence and predictors of anemia. Although anemia does not seem to be a major concern in this sample, it does not exclude the possibility of higher risk in more vulnerable groups within the farmworker population, such as indigenous workers and undocumented workers who may be less likely to be employed on a farm that is willing to allow a research team to recruit on site. More work is needed to better understand risk of anemia and obesity among farmworkers and factors that influence their physical work capacity, which may in turn influence earnings. Information on inflammation and iron status biomarkers, differing types of adiposity, diet, and food security may help clarify relationships between obesity and anemia in this population.

REFERENCES

1. California Agricultural Production Statistics: 2019 Crop Year—Top 10 Commodities for California Agriculture. 2019. Available at: http://www.cdfa.ca.gov/statistics/. Accessed September 26, 2020.
2. Martin PL, Hooker B, Akhtar M, Stockton M. How many workers are employed in California agriculture? *California Agriculture*. 2017;71:30–34.
3. Wirth C, Strochlic R, Getz C. *Hunger in the Fields: Food Insecurity Among Farmworkers in Fresno County*. Davis, CA: California Institute for Rural Studies; 2007.
4. Hernandez T, Gabbard S. *Findings from the National Agricultural Workers Survey (NAWS) 2015–2016: a demographic and employment profile of United States farmworkers*. Washington, DC: Department of Labor, Employment and Training Administration; 2019: 84 p.
5. Mines R, Nichols S, Runsten D. California's Indigenous Farmworkers: Final Report of the Indigenous Farmworker Study (IFS) To the California Endowment. California: Indigenous Farmworker Study; 2010. Available at: http://indigenousfarmworkers.org/IFS%20Full%20Report%20_Jan2010.pdf. Accessed June 29, 2022.
6. Stoecklin-Marois MT, Hennessy-Burt TE, Butler LM, Schenker MB. Immigration and acculturation factors related to weight perceptions and BMI in California hired farm workers. *Ann Epidemiol*. 2007;17:723–724.
7. Mitchell DC, Andrews T, Schenker MB. Pasos Saludables: a pilot randomized intervention study to reduce obesity in an immigrant farmworker population. *J Occup Environ Med*. 2015;57:1039–1046.
8. Qenani E, Roy S, MacDougall N. Vigorous physical work and obesity?—the paradox of the Californian farmworker population. *J Racial Ethn Health Disparities*. 2017;4:696–705.
9. Moore KL, Mercado J, Hill J, Katz SC. Disparities in health insurance coverage and health status among farmworkers, Sonoma County, California, 2013–2014. *Prev Chronic Dis*. 2016;13:E45.
10. Dixon LB, Winkleby MA, Radimer KL. Dietary intakes and serum nutrients differ between adults from food-insufficient and food-sufficient families: Third National Health and Nutrition Examination Survey, 1988–1994. *J Nutr*. 2001; 131:1232–1246.
11. Cepeda-Lopez AC, Melse-Boonstra A, Zimmermann MB, Herter-Aeberli I. In overweight and obese women, dietary iron absorption is reduced and the enhancement of iron absorption by ascorbic acid is one-half that in normal-weight women. *Am J Clin Nutr*. 2015;102:1389–1397.
12. Weiss G, Ganz T, Goodnough LT. Anemia of inflammation. *Blood*. 2019;133: 40–50.
13. Villarejo D, McCurdy SA, Bade B, Samuels S, Lighthall D, Williams D 3rd. The health of California's immigrant hired farmworkers. *Am J Ind Med*. 2010;53: 387–397.

14. Weigel MM, Armijos RX, Hall YP, Ramirez Y, Orozco R. The household food insecurity and health outcomes of U.S.–Mexico border migrant and seasonal farmworkers. *J Immigr Minor Health*. 2007;9:157–169.
15. Scholz BD, Gross R, Schultink W, Sastroamidjojo S. Anaemia is associated with reduced productivity of women workers even in less-physically-strenuous tasks. *Br J Nutr*. 1997;77:47–57.
16. Tsai K-Z, Lai S-W, Hsieh C-J, et al. Association between mild anemia and physical fitness in a military male cohort: the CHIEF study. *Sci Rep*. 2019;9:11165.
17. Gardner GW, Edgerton VR, Senewiratne B, Barnard RJ, Ohira Y. Physical work capacity and metabolic stress in subjects with iron deficiency anemia. *Am J Clin Nutr*. 1977;30:910–917.
18. Gledhill N. The influence of altered blood volume and oxygen transport capacity on aerobic performance. *Exerc Sport Sci Rev*. 1985;13:75–93.
19. Steeves JA, Tudor-Locke C, Murphy RA, King GA, Fitzhugh EC, Harris TB. Classification of occupational activity categories using accelerometry: NHANES 2003–2004. *Int J Behav Nutr Phys Act*. 2015;12:89.
20. Villarejo D. *A New Paradigm Is Needed for Labor Relations in Agriculture: California Agriculture and Farm Labor 1975−2014*. Davis, CA: California Institute for Rural Studies; 2015.
21. Mitchell DC, Castro J, Armitage TL, et al. Recruitment, methods, and descriptive results of a physiologic assessment of latino farmworkers: the California Heat Illness Prevention Study. *J Occup Environ Med*. 2017;59:649–658.
22. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014;12:1495–1499.
23. Wallach J. EBT core blood analytes: alterations by diseases. Philadelphia, PA: Lippincott Williams and Wilkins; 2000.
24. Stoltzfus RJ, Dreyfuss ML. *Guidelines for the Use of Iron Supplements to Prevent and Treat Iron Deficiency Anemia*. Washington, DC: International Nutritional Anemia Consultative Group (INACG); 1998.
25. Cheuvront SN, Ely BR, Kenefick RW, Sawka MN. Biological variation and diagnostic accuracy of dehydration assessment markers. *Am J Clin Nutr*. 2010; 92:565–573.
26. Shah D. Healthy worker effect phenomenon. *Indian J Occup Environ Med*. 2009;13:77–79.
27. Kroker-Lobos MF, Pedroza-Tobías A, Pedraza LS, Rivera JA. The double burden of undernutrition and excess body weight in Mexico. *Am J Clin Nutr*. 2014;100:1652S–1658S.
28. Wysocki M, Krotkiewski M, Braide M, Bagge U. Hemorheological disturbances, metabolic parameters and blood pressure in different types of obesity. *Atherosclerosis*. 1991;88:21–28.
29. Le CH. The prevalence of anemia and moderate-severe anemia in the US population (NHANES 2003–2012). *PLoS One*. 2016;11:e0166635.
30. Paltiel O, Clarfield AM. Anemia in elderly people: risk marker or risk factor? *CMAJ*. 2009;181(3–4):129–130.
31. Reid A, Schenker MB. Hired farmworkers in the US: demographics, work organisation, and services. *Am J Ind Med*. 2016;59:644–655.
32. Overweight & Obesity Statistics. 2017. Available at: https://www.niddk.nih.gov/health-information/health-statistics/overweight-obesity. Accessed September 26, 2020.
33. Rodriquez EJ, Stoecklin-Marois MT, Hennessy-Burt TE, Tancredi DJ, Schenker MB. Demographic and migration-related risk factors for low-level smoking in a farm working sample of Latinos (the MICASA study). *Field Actions Sci Rep*. 2014;20:3286–3286.
34. Chiolero A, Faeh D, Paccaud F, Cornuz J. Consequences of smoking for body weight, body fat distribution, and insulin resistance. *Am J Clin Nutr*. 2008;87: 801–809.
35. Matias SL, Stoecklin-Marois MT, Tancredi DJ, Schenker MB. Adherence to dietary recommendations is associated with acculturation among Latino farm workers. *J Nutr*. 2013;143:1451–1458.
36. Mitchell DC, Castro J, Armitage TL, Tancredi DJ, Bennett DH, Schenker MB. Physical activity and common tasks of California farm workers: California Heat Illness Prevention Study (CHIPS). *J Occup Environ Hyg*. 2018;15: 857–869.
37. *Iron Deficiency Anaemia Assessment, Prevention and Control: A guide for programme managers*. Geneva, Switzerland: World Health Organization; 2001.
38. Nordenberg D, Yip R, Binkin NJ. The effect of cigarette smoking on hemoglobin levels and anemia screening. *JAMA*. 1990;264:1556–1559.
39. Van Tiel E, Peeters PH, Smit HA, et al. Quitting smoking may restore hematological characteristics within five years. *Ann Epidemiol*. 2002;12:378–388.
40. Heuer L, Lausch C. Living with diabetes: perceptions of hispanic migrant farmworkers. *J Community Health Nurs*. 2006;23:49–64.
41. Sandberg JC, Grzywacz JG, Talton JW, et al. A cross-sectional exploration of excessive daytime sleepiness, depression, and musculoskeletal pain among migrant farmworkers. *J Agromedicine*. 2012;17:70–80.
42. Behan PO. Chronic fatigue syndrome as a delayed reaction to chronic low-dose organophosphate exposure. *J Nutr Environ Med*. 1996;6:341–350.
43. Bethel JW, Harger R. Heat-related illness among Oregon farmworkers. *Int J Environ Res Public Health*. 2014;11.
44. Ramos AK, Carvajal-Suarez M, Trinidad N, et al. A cross-sectional study of gender-related differences in reporting fatigue and pain among Latino/A migrant farmworkers. *J Agromedicine*. 2020;25:319–329.

