Daily Patterns of Caffeine Intake and the Association of Intake with Multiple Sociodemographic and Lifestyle Factors in US Adults Based on the NHANES 2007–2012 Surveys

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ABSTRACT

Background Caffeine increases alertness when consumed in single servings of various products including coffee, tea, soft drinks, and energy drinks. Although not a nutrient, caffeine is consumed by 90% of the adult population in the United States.

Objective This study examined the daily pattern of caffeine intake and its relationship to multiple demographic variables.

Methods Data from the National Health and Nutrition Examination Survey (NHANES) 2007–2012 (adults aged 19+ years; n=16,173) were used to determine the time of day at which caffeine is consumed and demographic factors associated with intake. Regression analyses characterized factors associated with caffeine intake including sex, age, ethnicity, education, smoking status, physical activity, employment status, total work hours, alcohol, and energy intake.

Results Mean adult per capita caffeine intake was 169±4 mg/d (mean±standard error). Most caffeine (70%) was consumed before noon, often at breakfast, and intake decreased progressively over the day, with little consumed after 9:00 PM. Intake was associated with age, ethnicity, smoking status, total calorie intake, and work hours ($P<0.01$) but not physical activity, economic status, education level, or employment status. Variables with the largest associations with intake were, respectively, ethnicity and age. Non-Hispanic black individuals consumed the smallest amounts (80±2 mg/d), non-Hispanic white individuals consumed the greatest amounts (194±3 mg/d), and Asian individuals (126±7 mg/d) and Hispanic individuals consumed intermediate amounts (127±3 mg/d). Middle-aged individuals (aged 50 to 54 years) consumed more caffeine (211±6 mg/d) than younger (107±4 mg/d, aged 20 to 24 years) and older individuals (153±4 mg/d, aged 75 to 79 years).

Conclusion Most caffeine is consumed in the morning, when alertness is lowest, and very little in the evening before sleep. Ethnicity and age were the variables most strongly associated with intake; work hours, occupation, energy and alcohol intake, and smoking were also associated with intake. Because caffeine increases alertness, it is not surprising that its pattern of consumption and factors associated with its intake vary from those of most other food constituents.
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APPROXIMATELY 90% OF ADULT AMERICANS REGUlarly consume caffeine, even though it is not a nutrient and can only be found in a limited number of products, unlike most common food constituents.[1] The major sources of caffeine in the American diet are coffee, tea, and cola beverages.[1-7] Almost 98% of caffeine is consumed in these beverages (coffee [~64%], soft drinks [~18%], and tea [~16%]).[6] Caffeine is also found in energy drinks and shots.[1-5,8] The health effects of caffeine are controversial, and numerous studies regularly appear in the literature addressing its benefits and risks.[9]

Because it is a stimulant, caffeine can have positive effects on mood, especially alertness, as well as cognitive performance, in relatively low doses in single servings of many foods; and its widespread popularity likely reflects these positive behavioral properties.[10-14] However, as a consequence of these properties, caffeine, especially when consumed later in the day in high doses, can interfere with sleep.[15-17]

Caffeine's effects are dose-dependent, and per capita daily intake by adults in the United States is about 186 mg/d and has been stable for 10 years and perhaps much longer.[1,18] Recently, introduction of new caffeine-containing products, especially energy drinks, has raised new concerns about its safety.[19-22] Regulatory authorities in various locations have considered the risks and benefits of caffeine consumption and reached varied conclusions.[23,24] The US Food and Drug Administration has noted that 400 mg/d caffeine is not typically associated with adverse effects among healthy adults but has expressed concerns about use by children and adolescents.[2,25] According to the Dietary Guidelines for Americans 2015–2020, moderate coffee consumption (up to 400 mg caffeine per day) can be incorporated into healthy eating patterns.[26] Only about 14% of US adults consume more than 400 mg caffeine per day.[1] Energy drinks make minor contributions[27] and account for less than 1% of intake.

Several demographic factors are associated with caffeine intake, such as tobacco use, age, and sex.[1,5,28] However, most data on individual factors associated with caffeine intake were collected from nonrepresentative samples and are out of date.[29] In spite of considerable scientific, public heath, regulatory, and lay interest in caffeine, a comprehensive evaluation of the demographic factors associated with caffeine intake and daily pattern of use in a large representative sample of US adults has never been conducted. Identification of demographic factors associated with caffeine intake may identify individuals most affected by availability of newer products, such as energy drinks. Because caffeine affects alertness and sleep in a dose-dependent manner, the time of day when it is consumed is critical for determining its behavioral effects. Therefore to determine the daily (hour-by-hour) pattern of caffeine intake and examine the relationships between intake and multiple demographic variables that could be associated with intake, a large representative sample of the US population (n=16,173) was studied using the National Health and Nutrition Examination Survey (NHANES) 2007–2012 datasets.[30]

Demographic and lifestyle variables known to be associated with caffeine intake are sex, age, smoking, and ethnicity. It was hypothesized that various factors not previously examined would also be associated with intake. These factors include energy intake, alcohol use, physical activity, education, socioeconomic status, employment status, weekly hours worked, and occupation.

METHODS

Participants

The continuous NHANES survey is conducted with a nationally representative sample of noninstitutionalized Americans by the Centers for Disease Control and Prevention National Center for Health Statistics, and data on approximately 5,000 adults are released every 2 years.[30] A complex, stratified, multistage probability cluster sampling design is used to collect these cross-sectional data. Survey participants are interviewed for demographic, socioeconomic, dietary (24-hour dietary recall), and general health information. Survey design and data collection procedures are available elsewhere.[30] All participants or proxies provided written informed consent, and the Research Ethics Review Board at the National Center for Health Statistics approved the protocol. Data from NHANES 2007–2008, 2009–2010, and 2011–2012 were combined for these analyses. The combined sample included 16,173 adults (aged 19 years and older) and excluded pregnant or lactating women, individuals reporting no food intake, and those with missing data (Figure 1).

RESEARCH SNAPSHOT

Research Question: What is the daily pattern of caffeine intake in adults in the United States and what are the demographic variables that are associated with intake?

Key Findings: In this cross-sectional study of 16,173 adults from the National Health and Nutrition Examination Survey 2007–2012, mean per capita caffeine intake was 169±4 mg/d (mean±standard error), and most was consumed in the morning. Ethnicity and age were the most important variables associated with caffeine intake.

Assessment of Caffeine Intake

The amount of caffeine consumed was estimated from consumption of all caffeine-containing foods and beverages, including energy drinks, but did not include dietary supplements and medications, which are minor sources of caffeine in the diet.[31,32] Participants were asked whether the beverages they consumed were caffeine free. The most up-to-date database provided by the US Department of Agriculture contains codes for 109 coffee drinks (including brewed, instant, espresso, etc), 45 different tea drinks (including hot/iced, black/green tea), and 21 energy drinks and provides detailed data on the composition of these beverages.[33] Caffeine consumers were defined as individuals who ingested foods or beverages containing caffeine during the first 24-hour dietary recall conducted.

Statistical Analysis

Analyses were conducted using SAS 9.2[34] and SUDAAN[35]. Appropriate weighting factors were used to adjust for oversampling of selected groups, survey nonresponse of some individuals, and day of the week when the interview was conducted. For assessment of hourly caffeine intake, day 1 dietary recall data were used. For all other analyses, individual usual caffeine intake was used as determined by the National Cancer Institute method utilizing 2 days of dietary recalls after adjusting for day-of-week of 24-hour recall (weekend or weekday) and sequence of dietary recall, using the single-component model, since caffeine is consumed by most people on most days.[36] Usual intake is a normally distributed estimate of long-term intake, whereas the 24-hour single-day intake is considered to be an estimate of acute intake on the day of recall.

Regression analyses were conducted to assess sociodemographic and lifestyle factors associated with individual usual caffeine intake and characterize factors associated with intake while controlling for other variables. Initial regression models included age (linear and quadratic components), sex, ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and "other" for NHANES 2007–2012, as well as Asian, for NHANES 2011–2012), physical activity (using Global Physical Activity Questionnaire providing work scores, walk scores,

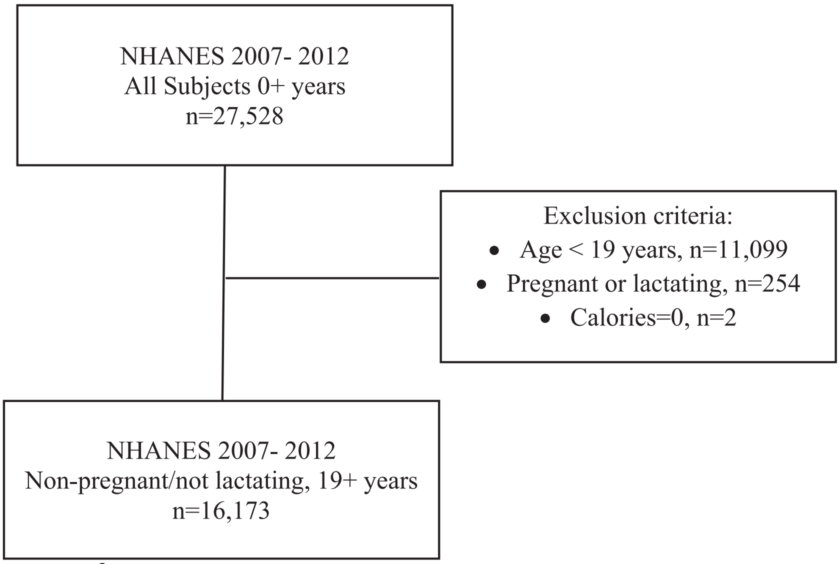

Figure 1. Participant flow chart. [a]NHANES=National Health and Nutrition Examination Survey.

and recreational scores), education level (<high school; high school; >high school), current smoking status, individual usual intakes of energy (calories per day), and alcohol intake (above/below the median) (model 1).

Data for three variables—work hours, employment status, and occupation—were only available for NHANES 2007–2010; thus additional regression analyses were conducted in which employment status (model 2) and weekly work hours (model 3) were also included. The adjusted mean caffeine intake of each occupation was also compared with the adjusted mean of all other occupations. Data are presented as means±standard errors. Significance was set at $P<0.01$.

RESULTS

Adult Caffeine Intake

Mean per capita individual usual caffeine intake among all adults aged 19 years and older was 169±4 mg/d (189±5 mg/d for men; 149±3 mg/d for women), and mean intake among adult caffeine consumers only (after excluding all individuals with zero caffeine intake) was 181±4 mg/d (206±5 mg/d for men; 159±3 mg/d for women). Caffeine intake was greatest between 6:00 and 9:00 AM and fell off progressively throughout the rest of the day. Most caffeine was consumed during the morning hours (Figure 2). About 70% of daily caffeine intake was ingested between 3:00 AM and noon, and about 40% of daily intake was consumed between 6:00 AM and 9:00 AM. Evening caffeine intake was low, with 7% to 8% consumed between 6:00 PM and 9:00 PM (Figure 2; Table 1).

Approximately 60% of total caffeine intake was consumed with defined meals. The breakfast meal was most commonly associated with intake, accounting for 39%. Intake at lunch (11%) or dinner (9%) was modest. Nonmeal occasions accounted for about 40% of caffeine intake.

Factors Associated with Usual Caffeine Intake

Usual intake of caffeine was significantly associated with ethnicity ($P<0.0001$). Non-Hispanic black individuals (−59%), Hispanic individuals (−34%), Asian individuals (∼−35%), and those with other ethnicities (−26%) consumed less caffeine than non-Hispanic white individuals (Table 2; Table 3, model 1). These associations remained significant ($P<0.0001$) when the data were also adjusted for employment status (model 2) or weekly work hours (model 3) or when poverty income ratio (PIR) replaced educational level in models (data not shown).

There was a curvilinear relationship between caffeine intake and age ($P<0.0001$) (Table 3, model 1). Intake was greatest among individuals aged 50 to 54 years, lowest among individuals aged 20 to 24 years, and intermediate among those 70 to 74 years and 75 to 79 years (Table 2). The association of caffeine intake with age remained unchanged ($P<0.0001$) when the data were additionally adjusted for employment status (model 2) or weekly work hours (model 3) or when PIR replaced education level in models (data not shown). Caffeine intake was also associated with sex, with men consuming more caffeine (11 mg/d more; $P=0.0037$). However, sex differences were not significant ($P>0.01$) after adjustment for employment status (model 2) or weekly work hours (model 3) (Table 3).

Caffeine intake was associated with smoking status (smokers consumed 56 mg/d more caffeine than nonsmokers; $P<0.0001$) and caloric intake (30 mg/d more caffeine was consumed for every additional 1,000 kcal of intake; $P<0.0001$) (Table 3). These associations remained significant ($P<0.0001$) when the data were additionally adjusted for employment status (model 2) or weekly work hours (model 3) or when PIR replaced education level in models (data not shown). Caffeine intake was associated with alcohol intake (12 to 13 mg/d more caffeine was consumed by those with greater than median alcohol intake compared with those with lower than median alcohol intake; $P<0.01$; NHANES 2007–2010) but only when the data were additionally adjusted for employment status (model 2) or weekly work hours (model 3). Caffeine intake was positively associated ($P<0.01$) with weekly work hours but not associated

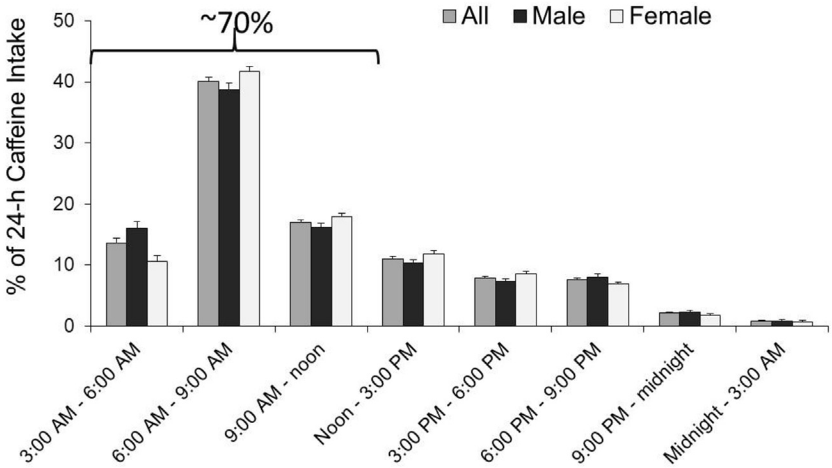

Figure 2. Daily caffeine intake (%) by time of day among adults aged 19 years and older (n=16,173; 8,090 male, 8,083 female; National Health and Nutrition Examination Survey 2007–2012).

(P>0.01) with physical activity, PIR (data not shown), education level, or employment status (Table 3).

Caffeine intake was associated with certain occupations (Table 2). Average unadjusted caffeine intake was 180±5 mg/d among those employed, significantly higher (P<0.0001) than among those reporting no occupation (unemployed/retired/seeking employment; 156±5 mg/d). After adjusting for covariates, the difference in caffeine intake among those employed and those who were not was no longer significant (P=0.0527; model 2). However, working in "legal" and "management" occupations was associated with greater caffeine intake (increases of 55 mg/d and 23 mg/d, respectively) than the average of all other occupations (P<0.01; NHANES 2007–2010) (model 2). When the data were additionally adjusted for weekly work hours (model 3), "legal" and "management" occupations were not associated with more caffeine intake; however, "building, grounds cleaning, maintenance" occupation was significantly associated with less caffeine intake (34 mg/d less than the average of all other occupations, P<0.01) (Table 2).

Table 1. Daily caffeine intake (%) by time of day among adults aged 19 years and older (n=16,173; 8,090 men and 8,083 women; NHANES[a] 2007–2012)

	% of 24-h Caffeine Intake (mean±SE[b])		
Time of day	**All**	**Men**	**Women**
3:00 AM to 6:00 AM	13.62±0.80	16.04±1.08	10.61±0.90
6:00 AM to 9:00 AM	40.01±0.75	38.68±1.10	41.67±0.91
9:00 AM to noon	16.97±0.44	16.22±0.58	17.90±0.61
Noon to 3:00 PM	11.05±0.33	10.39±0.49	11.87±0.50
3:00 PM to 6:00 PM	7.87±0.28	7.32±0.43	8.55±0.43
6:00 PM to 9:00 PM	7.56±0.27	8.06±0.45	6.93±0.34
9:00 PM to midnight	2.13±0.14	2.39±0.18	1.81±0.20
Midnight to 3:00 AM	0.79±0.16	0.89±0.17	0.67±0.29

[a]NHANES=National Health and Nutrition Examination Survey.
[b]SE=standard error.

DISCUSSION

This study assessed daily patterns of usual caffeine intake and examined an extensive series of demographic factors to determine their association with caffeine intake. Current levels of caffeine intake are well within levels considered safe.[26,37] Most caffeine is consumed in the morning hours, often at breakfast, and little is consumed after 9:00 PM. Ethnicity, age, work hours, occupation, energy intake, and smoking were independent variables associated with caffeine intake, but sex was not after controlling for the other factors.

Because caffeine is only present in a very limited number of foods, individuals can readily choose whether and when they wish to consume it. Caffeine's ability to increase alertness and improve cognitive performance in doses found in single servings of beverages are well documented in the popular[38] and scientific literature.[39-41] About 90% of US adults consume caffeine regularly, and this study demonstrates that adults consume more than two-thirds of their total daily intake in the morning hours. This is the opposite pattern of daily food intake, which increases over the course of the day with the largest meal usually consumed in the evening.[42]

Daily patterns of human alertness are governed by circadian rhythms and follow a regular pattern; alertness is at a nadir on arising in the morning, increases over the next few hours, and decreases in the evening before the onset of sleep.[17,29] The extent of morning drowsiness is described in part by the phenomenon of sleep inertia, which can be present for several hours after awakening.[43] Data presented here indicate that the vast majority of the US population intentionally chooses to consume caffeine in the morning, most commonly in the form of coffee. This is when arousal is typically lowest and sleep inertia is greatest and, therefore, is the most appropriate time to consume caffeine to increase arousal and counteract sleep inertia.[29] Well-controlled studies demonstrate caffeine administration speeds recovery from drowsiness associated with sleep inertia.[44,45]

Table 2. Usual intake of caffeine among adults (aged 19 years and older, sex combined, NHANES[a] 2007−2012) by demographic variables

Variable	Caffeine (mg/d) mean±SE[b]
Race/ethnicity	
Non-Hispanic white	194±3
Hispanic	127±3[c]
Non-Hispanic black	80±2[c]
Other	144±4[c]
Asian[d]	126±7[c]
Age, y[e]	
20-24	107±4
25-29	123±4
30-34	168±6
35-39	164±5
40-44	194±6
45-49	194±6
50-54	211±6
55-59	196±5
60-64	199±4
65-69	202±9
70-74	177±6
75-79	153±4
Occupation[f]	
Legal	220±15[g]
Management	188±6[g]
Business, financial operations	188±12
Protective service	188±13
Installation, maintenance, repair	185±18
Transportation, material moving	183±15
Construction, extraction	182±14
Health care practitioner, technical	174±9
Education, training, library	174±9
Production	173±10
Computer, mathematical	172±12
Food preparation, serving	171±7
Office, administrative support	170±7
Community, social services	168±14
Sales, related	168±8
Architecture, engineering	166±16
Personal care, service	165±10
Health care support	165±8
Arts, design, entertainment, sports, media	163±17
Farming, fishing, forestry	159±16
Building, grounds cleaning, maintenance	153±6[h]
Life, physical, social science	146±15

(continued)

Table 2. Usual intake of caffeine among adults (aged 19 years and older, sex combined, NHANES[a] 2007−2012) by demographic variables (*continued*)

[a]NHANES=National Health and Nutrition Examination Survey.
[b]SE=standard error.
[c]Significantly different from non-Hispanic white at $P<0.01$ after adjusting for age, sex, physical activity, smoking status, energy intake, alcohol intake, education, occupation, employment status, and work hours.
[d]Asian cohort data were only available in 2011−2012 in which non-Hispanic white intake was 192±4 mg/d.
[e]Linear and quadratic components for age were significant at $P<0.01$.
[f]Occupation data were only available in 2007−2010.
[g]Significantly different from mean of all others excluding those who had no occupation (unemployed/retired/seeking employment) at $P<0.01$ after adjusting for age, sex, ethnicity, physical activity, smoking status, energy intake, alcohol intake, education, occupation, and employment status.
[h]Significantly different from mean of all others at $P<0.01$ after additionally adjusting for work hours.

This study also demonstrates that US adults consciously avoid consuming caffeine in the evening when preparing for sleep. Only 2% of caffeine intake occurs between 9:00 PM and midnight, when most individuals are preparing for sleep.[46] In a small, nonrepresentative sample of the British general population (n=122), a similar pattern of daily caffeine intake was observed and attributed to the perceived behavioral effects of caffeine.[29]

Caffeine intake has been strongly associated with several demographic and lifestyle variables but not others. Previous studies have not examined such an extensive series of demographic factors and controlled for their effects in multiple regression analyses. Race/ethnicity was strongly associated with caffeine intake. Non-Hispanic black individuals consumed 59% less caffeine than non-Hispanic white individuals. Hispanic and Asian individuals and members of other ethnic groups also consumed less caffeine than non-Hispanic white individuals. Previous studies included observations on some of these relationships but did not consider or control for multiple variables examined in this study: age, sex, ethnicity, physical activity, PIR, smoking status, intake of energy and alcohol, education, employment, and work hours.

Controlling for other demographic and lifestyle variables is important, given the change in association of caffeine intake with sex; there was a difference of 40 mg/d between men and women in unadjusted data, but after controlling for some demographic variables, the difference was only 10 mg/d. In addition, there does not appear to be any published data on the caffeine intake of Asian Americans. An explanation for substantial racial differences in caffeine intake is not apparent. Genetic factors and cultural differences may each account for a portion of the variation. There are racial and ethnic differences in activity of CYP1A2, a caffeine-metabolizing enzyme,[47] and excretion of caffeine and its

Table 3. Demographic factors associated with adjusted usual caffeine intake in NHANES[a] 2007–2012

Factors	Model 1[b] $R^2=0.24$		Model 2[c] $R^2=0.25$		Model 3[d] $R^2=0.25$	
	β (99% CI)	*P* value	β (99% CI)	*P* value	β (99% CI)	*P* value
Ethnicity						
Non-Hispanic black vs non-Hispanic white	−115 (−123, −106)	<0.0001	−116 (−127, −106)	<0.0001	−116 (−126, −105)	<0.0001
Hispanic vs non-Hispanic white	−67.0 (−78.2, −55.7)	<0.0001	−66.1 (−79.8, −52.3)	<0.0001	−66.1 (−80.1, −52.2)	<0.0001
Asian vs non-Hispanic white[e]	−65.9 (−89.4, −42.5)	<0.0001				
Others vs non-Hispanic white	−50.2 (−59.9, −40.5)	<0.0001	−46.9 (−61.1, −32.7)	<0.0001	−46.8 (−61.3, −32.4)	<0.0001
Age (linear), y	10.4 (9.04, 11.7)	<0.0001	10.4 (8.56, 12.3)	<0.0001	10.1 (8.26, 11.9)	<0.0001
Age (quadratic), y	−0.10 (−0.11, −0.08)	<0.0001	−0.09 (−0.11, −0.08)	<0.0001	−0.09 (−0.11, −0.07)	<0.0001
Sex						
Male vs female	10.7 (1.29, 20.0)	0.0037	7.94 (−2.81, 18.7)	0.0513	6.14 (−4.74, 17.0)	0.1316
Smokers vs nonsmokers	56.3 (44.4, 68.2)	<0.0001	63.3 (48.6, 77.9)	<0.0001	64.3 (49.7, 79.0)	<0.0001
Energy intake (per 1,000 kcal difference)	30.3 (15.7, 45.0)	<0.0001	32.3 (12.3, 52.4)	0.0001	32.1 (12.0, 52.1)	0.0001
Alcohol (g/d above median vs below median)	7.53 (−1.51, 16.6)	0.0300	12.5 (0.62, 24.4)	0.0070	12.0 (0.14, 23.8)	0.0092
Physical activity (MET[f] min/day)						
Work score	0.0004 (−0.0005, 0.001)	0.2588	0.0002 (−0.001, 0.001)	0.6360	0.00003 (−0.001, 0.001)	0.9347
Walk score	−0.001 (−0.004, 0.002)	0.2415	−0.001 (−0.005, 0.003)	0.5688	−0.001 (−004, 0.003)	0.6418
Recreational score	−0.002 (−0.004, −0.0001)	0.0077	−0.001 (−0.004, 0.002)	0.3193	−0.001 (−0.003, 0.002)	0.3590
Education <high school	1.43 (−12.2, 15.0)	0.7784	2.18 (−14.5, 18.9)	0.7229	2.45 (−14.2, 19.0)	0.6888
Education >high school	5.10 (−4.63, 14.8)	0.1653	3.01 (−7.41, 13.4)	0.4312	2.20 (−8.51, 12.9)	0.5771
Employment status			8.10 (−3.08, 19.3)	0.0556		
Work hours (per 40-h work week)					15.0 (3.42, 26.6)	0.0012

[a]NHANES=National Health and Nutrition Examination Survey.
[b]Data from NHANES 2007–2012. Model 1 (initial regression model) included age, sex, ethnicity, education level, physical activity, smoking status, energy intake and alcohol intake.
[c]Data from NHANES 2007–2010. Model 2 included factors in model 1 and employment status.
[d]Data from NHANES 2007–2010. Model 3 included factors in model 1, factors in model 2, and weekly work hours.
[e]Data from NHANES 2011–2012 for Asians.
[f]MET=metabolic equivalents.

metabolites.[28,48] Genetic factors associated with behavioral effects of caffeine, such as variability in adenosine A_2 receptors,[49,50] may account, in part, for racial differences in intake. There are, of course, substantial long-standing cultural differences in patterns of beverage consumption, such as a preference for tea, which contains less caffeine than coffee, by many Asian populations.

In this study, age was also associated with caffeine intake. Because of the popularity of energy drinks, there has been some concern that young adults may be consuming excessive amounts of caffeine,[19-22] but in this study, those aged 20 to 24 years consumed substantially less caffeine than those aged 50 to 79 years. Nevertheless, given the growing popularity of these products, continued monitoring of caffeine consumption by younger populations is warranted. Previous studies have also revealed a similar association of caffeine intake with age[1,28,51] but did not control for hours at work, employment status, or education.

The reasons for the strong association of caffeine with age are not apparent, but unlike race, they could not be genetic.

Perhaps as the demands of life increase over the lifespan, for example, work and family responsibilities such as child care that typically reach the maximum in middle age, caffeine is used to maintain alertness/cognitive function. Middle-aged individuals typically get less sleep than younger and older individuals—indirect support for this hypothesis.[52] The finding that weekly work hours are positively associated with caffeine intake also supports this hypothesis.

Caffeine intake was also related to an individual's profession/occupation. Adults in "legal" or "management" professions consumed more caffeine than adults in other professions. Because caffeine increases alertness and reduces fatigue,[10,39,53-55] its use by individuals in these occupations may reflect the demanding nature of their professions. When the data were additionally adjusted for weekly work hours, the association with working in the "legal" and "management" professions was no longer significant, a finding that supports this hypothesis. In addition, those in "building, grounds cleaning, maintenance" occupations consumed less caffeine than individuals with other occupations after adjustment for work hours, perhaps because they have less access to caffeine-containing beverages than office workers. The positive association of caffeine and tobacco use observed is well-documented.[29,48,56]

It is usually reported that men consume more caffeine than women, as observed in this study in a partially adjusted model (model 1).[1,27,57] However, the association of sex with caffeine was not significant when additionally adjusted for employment status (model 2) or work hours (model 3) indicating these covariates could be responsible for sex-related differences in intake typically reported.[1,27,57] As expected, caffeine intake was also associated with total calorie intake. Overall, the various sociodemographic variables included in the models in the present study account for about 25% of individual variation in caffeine intake.

One limitation of this study, and others in which 24-hour dietary recalls are used, is possible underreporting of intake, a potential source of bias. In addition, estimates of caffeine intake were based on database values, and given levels may vary by product type can be imprecise. A major strength of this study was use of a large nationally representative population-based sample of adults. In addition, this is one of the first studies to simultaneously examine an extensive series of demographic and lifestyle factors associated with caffeine intake and control for effects of other variables in multiple regression analyses using a nationally representative dataset large enough to permit such analyses.

CONCLUSION

Most caffeine is consumed in the morning, perhaps to increase alertness, which is lowest at this time; and very little is consumed after 9:00 PM, presumably to avoid disrupting sleep. Ethnicity and age are particularly important demographic variables associated with caffeine intake. Since caffeine increases alertness in doses found in single servings of many beverages, and its popularity appears to result in part from this unique property, it is not surprising that demographic factors associated with its intake differ from those typically associated with intake of other food components.

References

1. Fulgoni VL, Keast DR, Lieberman HR. Trends in intake and sources of caffeine in the diets of US adults: 2001—2010. *Am J Clin Nutr*. 2015;101(5):1081-1087.
2. Nawrot P, Jordan S, Eastwood J, Rotstein J, Hugenholtz A, Feeley M. Effects of caffeine on human health. *Food Addit Contam*. 2003;20(1):1-30.
3. Andrews KW, Schweitzer A, Zhao C, et al. The caffeine contents of dietary supplements commonly purchased in the US: Analysis of 53 products with caffeine containing ingredients. *Anal Bioanal Chem*. 2007;389(1):231-239.
4. Heckman MA, Weil J, Gonzalez de Mejia E. Caffeine (1, 3, 7-trimethylxanthine) in foods: A comprehensive review on consumption, functionality, safety, and regulatory matters. *J Food Sci*. 2010;75(3):R77-R87.
5. Mitchell DC, Knight CA, Hockenberry J, Teplansky R, Hartman TJ. Beverage caffeine intakes in the U.S. *Food Chem Toxicol*. 2014;63:136-142.
6. Institute of Medicine. *Caffeine for the Sustainment of mental Task Performance*. Washington, DC: National Academies Press; 2001.
7. Frary CD, Johnson RK, Wang MQ. Food sources and intakes of caffeine in the diets of persons in the United States. *J Am Diet Assoc*. 2005;105(1):110-113.
8. Bailey RL, Saldanha LG, Dwyer JT. Estimating caffeine intake from energy drinks and dietary supplements in the United States. *Nutr Rev*. 2014;72(suppl 1):S9-S13.
9. Wikoff D, Welsh BT, Henderson R, et al. Systematic review of the potential adverse effects of caffeine consumption in healthy adults, pregnant women, adolescents, and children. *Food Chem Toxicol*. 2017;109(Pt 1):585-648.
10. Goldstein A, Kaizer S. Psychotropic effects of caffeine in man. III. A questionnaire survey of coffee drinking and its effects in a group of housewives. *Clin Pharm Ther*. 1969;10(4):477-488.
11. Smit HJ, Rogers PJ. Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers. *Psychopharmacology (Berl)*. 2000;152(2):167-173.
12. Brice CF, Smith AP. Effects of caffeine on mood and performance: A study of realistic consumption. *Psychopharmacology (Berl)*. 2002;164(2):188-192.
13. Smith A. Effects of caffeine in chewing gum on mood and attention. *Hum Psychopharmacol*. 2009;24(3):239-247.
14. Mahoney CR, Giles GE, Marriott BP, et al. Intake of caffeine from all sources and reasons for use by college students. *Clin Nutr*; 2018 Apr 10. pii: S0261-5614(18)30134-1.
15. Smith AP, Maben A, Brockman P. The effects of caffeine and evening meals on sleep and performance, mood and cardiovascular functioning the following day. *J Psychopharmacol*. 1993;7(2):203-206.
16. Hindmarch I, Rigney U, Stanley N, Quinlan P, Rycroft J, Lane J. A naturalistic investigation of the effects of day-long consumption of tea, coffee and water on alertness, sleep onset and sleep quality. *Psychopharmacology (Berl)*. 2000;149(3):203-216.
17. Bonnet MH, Arand DL. Insomnia, metabolic rate and sleep restoration. *J Intern Med*. 2003;254(1):23-31.
18. Institute of Medicine. *Caffeine in Food and Dietary Supplements: Examining Safety: Workshop Summary*. Washington, DC: The National Academies Press; 2014.
19. Torpy JM, Livingston EH. Energy drinks. *JAMA*. 2013;309(3):297.
20. Breda JJ, Whiting SH, Encarnaçao R, et al. Energy drink consumption in Europe: A review of the risks, adverse health effects, and policy options to respond. *Front Public Health*. 2014;2:134.
21. Ali F, Rehman H, Babayan Z, Stapleton D, Joshi DD. Energy drinks and their adverse health effects: A systematic review of the current evidence. *Postgrad Med*. 2015;127(3):308-322.
22. Richards G, Smith AP. A review of energy drinks and mental health, with a focus on stress, anxiety, and depression. *J Caffeine Res*. 2016;6(2):49-63.
23. Australia New Zealand Food Authority. Report from the Expert Working Group on Safety Aspects of Dietary Caffeine. 2000. http://www.foodstandards.gov.au/publications/Documents/safety%20aspects%20of%20dietary%20caffeine.pdf. Accessed July 1, 2016.
24. European Food Safety Authority. Scientific opinion on the safety of caffeine. *EFSA Journal*. 2015;13(5):4102.

25. US Food and Drug Administration. FDA to investigate added caffeine. FDA Consumer Health Information. 2013. http://www.fda.gov/downloads/ForConsumers/ConsumerUpdates/UCM350740.pdf. Accessed July 6, 2016.
26. US Department of Health and Human Services and US Department of Agriculture. 2015−2020 Dietary Guidelines for Americans. 8th ed. 2015. http://health.gov/dietaryguidelines/2015/guidelines/. Accessed July 9, 2018.
27. Drewnowski A, Rehm CD. Sources of caffeine in diets of US children and adults: Trends by beverage type and purchase location. *Nutrients*. 2016;8:154.
28. Rybak ME, Sternberg MR, Pao CI, Ahluwalia N, Pfeiffer CM. Urine excretion of caffeine and select caffeine metabolites is common in the U.S. population and associated with caffeine intake. *J Nutr*. 2015;145(4):766-774.
29. Brice CF, Smith AP. Factors associated with caffeine consumption. *Int J Food Sci Nutr*. 2002;53(1):55-64.
30. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey data, Hyattsville, MD. 2015. http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Accessed October 1, 2015.
31. Lieberman HR, Stavinoha T, McGraw S, White A, Hadden L, Marriott B. Caffeine use among active duty US Army soldiers. *J Acad Nutr Diet*. 2012;112(6):902-912.
32. Knapik JJ, Trone DW, McGraw SM, Steelman RA, Austin KG, Lieberman HR. Caffeine use among active duty navy and marine corps personnel. *Nutrients*. 2016;8(10):620.
33. US Department of Agriculture, Agricultural Research Service. USDA Food and Nutrient Database for Dietary Studies 2011-2012. Food Surveys Research Group Home Page. 2014 http://www.ars.usda.gov/ba/bhnrc/fsrg. Accessed October 1, 2015.
34. *SAS* [computer program]. Cary, NC: SAS Institute, Inc; 2008.
35. *SUDAAN* [computer program]. Release 11.0. Research Triangle Park, NC: Research Triangle Institute; 2012.
36. Tooze JA, Kipnis V, Buckman DW, et al. A mixed-effects model approach for estimating the distribution of usual intake of nutrients: The NCI method. *Stat Med*. 2010;29(27):2857-2868.
37. Alsharif S. Caffeine and exercise. 2015. Academy of Nutrition and Dietetics website. http://www.eatright.org/resource/fitness/sports-and-performance/fueling-your-workout/caffeine-and-exercise. Accessed November 18, 2017.
38. Reynolds G. This is your brain on coffee. *NY Times*. 2013. http://well.blogs.nytimes.com/2013/06/06/this-is-your-brain-on-coffee/. Accessed December 15, 2016.
39. McLellan TM, Caldwell JA, Lieberman HR. A review of caffeine's effects on cognitive, physical and occupational performance. *Neurosci Biobehav Rev*. 2016;71:294-312.
40. Amendola CA, Gabrieli JD, Lieberman HR. Caffeine's effects on performance and mood are independent of age and gender. *Nutr Neurosci*. 1998;1(4):269-280.
41. Smith A, Sturgess W, Gallagher J. Effects of a low dose of caffeine given in different drinks on mood and performance. *Hum Psychopharmacol Clin Exp*. 1999;14:473-482.
42. US Department of Agriculture, Agricultural Research Service. What We Eat In America Data Tables. 2017. https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/wweia-data-tables/. Accessed May 18, 2018.
43. Jewett ME, Wyatt JK, Ritz-De Cecco A, Khalsa SB, Dijk DJ, Czeisler CA. Time course of sleep inertia dissipation in human performance and alertness. *J Sleep Res*. 1999;8(1):1-8.
44. Van Dongen HP, Price NJ, Mullington JM, Szuba MP, Kapoor SC, Dinges DF. Caffeine eliminates psychomotor vigilance deficits from sleep inertia. *Sleep*. 2001;24(7):813-819.
45. Newman RA, Kamimori GH, Wesensten NJ, Picchioni D, Balkin TJ. Caffeine gum minimizes sleep inertia. *Percept Mot Skills*. 2013;116(1):280-293.
46. Walch OJ, Cochran A, Forger DB. A global quantification of "normal" sleep schedules using smartphone data. *Sci Adv*. 2016;2:e1501705.
47. McGraw J, Waller D. Cytochrome P450 variations in different ethnic populations. *Expert Opin Drug Metab Toxicol*. 2012;8(3):371-382.
48. Jain RB. Levels of caffeine and its metabolites among U.S. smokers and nonsmokers. *Environ Toxicol Pharmacol*. 2015;39(2):773-786.
49. Childs E, Hohoff C, Deckert J, Xu K, Badner J, de Wit H. Association between the ADORA2A and DRD2 polymorphisms and caffeine-induced anxiety. *Neuropsychopharmacol*. 2008;33(12):2791-2800.
50. Rogers PJ, Hohoff C, Heatherley SV, et al. Association of the anxiogenic and alerting effects of caffeine with ADORA2A and ADORA1 polymorphisms and habitual level of caffeine consumption. *Neuropsychopharmacol*. 2010;35(9):1973-1983.
51. US Department of Agriculture. Nutrient Intakes from Food and Beverages: Mean Amounts Consumed per Individual, by Gender and Age, What We Eat in America, NHANES 2011-2012. 2014. http://www.ars.usda.gov/SP2UserFiles/Place/80400530/pdf/1112/Table_1_NIN_GEN_11.pdf. Accessed July 6, 2016).
52. United States Department of Labor. Bureau of Labor Statistics. Average sleep times per day, by age and sex. 2015. https://www.bls.gov/tus/charts/chart16.pdf. Accessed December 7, 2016.
53. Smith A. Effects of caffeine on human behavior. *Food Chem Toxicol*. 2002;40(9):1243-1255.
54. Brunye TT, Mahoney CR, Lieberman HR, Taylor HA. Caffeine modulates attention network function. *Brain Cogn*. 2010;72(2):181-188.
55. Glade MJ. Caffeine-not just a stimulant. *Nutrition*. 2010;26(10):932-938.
56. Treur JL, Taylor AE, Ware JJ, et al. Associations between smoking and caffeine consumption in two European cohorts. *Addiction*. 2016;111(6):1059-1068.
57. Ahuja JKC, Goldman JD, Perloff BP. The effect of improved food composition data on intake estimates in the United States of America. *J Food Compost Anal*. 2006;19(suppl 1):S7-S13.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

S. Agarwal and V. L. Fulgoni III are nutrition consultants and provide services to industry; H. R. Lieberman reports no conflict of interest.

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AUTHOR CONTRIBUTIONS

H.R. Lieberman participated in formulating the research question, design of analyses, interpretation of the data, drafting the manuscript, and revising the manuscript; V.L. Fulgoni III participated in the design of analyses, NHANES dietary data analysis, interpretation of the data, drafting the manuscript, and revising the manuscript; S. Agarwal participated in interpretation of the data, drafting the manuscript, and revising the manuscript. All authors read and approved the final version of the paper and are responsible for all aspects of the paper.