Published in final edited form as:

Nutrition. 2016 ; 32(11-12): 1193–1199. doi:10.1016/j.nut.2016.04.005.

Caffeine consumption, insomnia, and sleep duration: Results from a nationally representative sample

Ninad S. Chaudhary, M.B.B.S., M.P.H.^{a,b,*}, Michael A. Grandner, Ph.D., M.T.R.^c, Nicholas J. Jackson, M.P.H., M.A.^d, and Subhajit Chakravorty, M.D.^{e,f}

^aDepartment of Emergency Medicine, UAB School of Medicine, Birmingham, AL

^bDepartment of Epidemiology, UAB School of Public Health, Birmingham, AL

^cUniversity of Arizona College of Medicine, Tucson, AZ

^dUniversity of Southern California, Los Angeles, CA

^eCorporal Michael J. Crescenz VA Medical Center, Philadelphia, PA

^fPerelman School of Medicine of the University of Pennsylvania, Philadelphia, PA

Abstract

Objective: Insomnia symptoms have been individually associated with both caffeine consumption and sleep duration abnormalities in prior studies. The goal of this study was to determine whether caffeine consumption was associated with insomnia symptoms from a population perspective and whether this relationship depended on habitual sleep duration.

Methods: Data were extracted from the 2007–2008 National Health and Nutritional Examination Survey (N = 4730). Caffeine consumption was quantified as mg/d from 2 typical days of use, 7 to 10 d apart. Insomnia symptoms were evaluated using frequencies of difficulty falling asleep (DFA), difficulty staying asleep (DSA), non-restorative sleep (NRS), and daytime sleepiness (DS). Habitual sleep duration was assessed as the hours of sleep obtained on a typical night. Binomial logistic regression analysis evaluated the relationships of individual insomnia and sleepiness symptoms (DFA, DSA, NRS, and DS) with caffeine consumption and sleep duration variables, after adjusting for covariates.

Results: The mean $\pm$ SD caffeine consumption was 176.6 ± 201 mg/d. Mean habitual sleep duration was 6.8 ± 1.4 h. Insomnia symptoms were prevalent in 19.1% to 28.4% of the respondents. Although caffeine consumption was associated with all insomnia symptoms in the unadjusted models, the adjusted models demonstrated a trend toward significance with DSA. Sleep duration was inversely associated with the insomnia symptoms in unadjusted and adjusted analysis. Finally, NRS was associated with an interaction between increased caffeine consumption and sleep duration.

Conclusion: The association between caffeine use and insomnia symptoms depends on habitual sleep duration at a population level.

*Corresponding author. Tel.: +1 (214) 842 2285; fax: +1 (205) 975-3329. Drminadsc@gmail.com (N. S. Chaudhary).

Keywords

Caffeine; Sleep deprivation; Sleep initiation and maintenance disturbance; Population; Anxiety

Introduction

Caffeine is one of the most frequently used psychoactive stimulant drugs. It is commonly used to ameliorate behavioral and cognitive performance deficits secondary to sleep deprivation [1,2]. Caffeine's use has been associated with an improvement in performance in healthy individuals even at a low dose of 32 mg [3]. Caffeinated chewing gum at a dose of 100 mg showed an improvement in neurobehavioral functioning after subacute sleep deprivation when compared with placebo [4]. Caffeine has been shown to improve performance after sleep deprivation of 21 h [5–8].

Despite its beneficial effects on sleep deprivation, caffeine may have adverse sleep-related consequences on subsequent nights. These sleep disruptive effects may be broadly classified as insomnia symptoms and abnormalities of sleep disruption. Nocturnal use of caffeine may lead to increased worrying at night and sleeplessness [9]. Other subjective insomnia symptoms demonstrated after caffeine consumption in healthy individuals have included decreased total sleep time, difficulty falling asleep, increased nocturnal awakenings, and daytime sleepiness [10–13]. Polysomnographic sleep abnormalities seen after caffeine consumption have included increased sleep latency, decreased stages 2 and 4 of non-rapid eye movement sleep, sleep fragmentation with brief arousals from sleep, and decreased sleep duration [11–18]. These sleep-related problems may be amplified in individuals with insomnia.

In addition to the generation or aggravation of sleep continuity problems, consumption of coffee and other caffeinated drinks has been associated with insufficient duration of sleep or short sleep duration. Short sleep duration has been defined as a total sleep time of <6 h per night and has been associated with a wide range of medical and psychiatric comorbidities [19]. In college students, a mean caffeine consumption of 3 to 5 cups of coffee/d was associated with habitual sleep duration of 6 h a night [20]. Other studies have linked caffeine consumption to short sleep duration and insomnia symptoms in specific populations, such as deployed military personnel [2], middle-aged professional drivers (ages 49–64 y) [21], and college students [14]. In a study of military personnel, consumption of 3 caffeinated beverages was associated with a sleep duration of 3 h a night [2]. In another study, consumers of 5 cups/d of coffee had significantly reduced total sleep duration along with fragmented sleep [14]. These positive findings contrast with that of another epidemiologic study that showed no association between sleep duration and caffeine use in middle-aged women [22].

In summary, the relationship of daily caffeine use and sleep duration and insomnia symptoms is unclear, especially when both insomnia symptoms and sleep duration are considered simultaneously. Additionally, findings from laboratory-based studies may not be valid at the community level, where other covariates may play a role in this relationship.

Thus, exploring these relationships at a population level will acquire significance for the following reasons:

1. About one-tenth of the US population already suffers from insomnia [23], and insufficient sleep duration is a widely prevalent sleep-related condition.
2. Caffeine is commonly used as a countermeasure for daytime consequences of inadequate sleep [2,24].
3. The population trends of caffeine consumption have increased exponentially over time since the arrival of and easy access to caffeinated energy drinks [25].
4. Laboratory studies have demonstrated that caffeine consumption may be associated with insomnia symptoms, especially in individuals who report higher baseline anxiety levels.

Accordingly, in the present study, the relationship between habitual caffeine use and insomnia symptoms was evaluated using a nationally representative data set. We hypothesized the following:

1. Heavier caffeine consumption, compared with light or no caffeine consumption, will be associated with higher insomnia symptoms and daytime sleepiness; and
2. A higher probability of experiencing insomnia symptoms will be associated with an interaction between higher caffeine consumption and lower sleep duration.

The existence of such a complex relationship will expand the understanding of how caffeine consumption interacts with insomnia symptoms and sleep duration at a population level.

Methods

Design and setting

The present study used cross-sectional data from the 2007–2008 wave of the National Health and Nutritional Examination Survey (NHANES). The NHANES is a nationally representative annual survey that evaluates health and nutritional characteristics of the US population. It is conducted through in-person interviews, and with physical examination and laboratory tests as needed. The 2007–2008 survey oversampled for African Americans, Hispanics, and adults age >60 y to compensate for underrepresentation [26]. The unweighted response rate for the overall sample was 78.4%.

Sample

From the original survey (N = 10 149), data were extracted from adult participants age ≥ 18 y for whom complete data was available on independent variables and covariates (n = 4730) (see Fig. 1).

Measures

Caffeine consumption—Caffeine intake was evaluated as the mean consumption from 2 typical days 7 to 10 d apart and was recorded in mg/d. Caffeine consumption was further

categorized into “none” (caffeine non-users), “light” (caffeine intake 120 mg/d), and “moderate-heavy” (>120 mg/d), as done in prior studies [27–29].

Sleep—Difficulty falling asleep (DFA) was assessed using the question “In the past month, how often did you have trouble falling asleep?” Difficulty staying asleep (DSA) was measured with the question, “In the past month, how often did you wake up during the night and had trouble getting back to sleep?” Non-restorative sleep (NRS) was evaluated using the question, “In the past month, how often did you feel unrested during the day, no matter how many hours of sleep you have had?” Daytime sleepiness (DS) was evaluated with the question, “In the past month, how often did you feel excessively or overly sleepy during the day?” The responses to these four sleep-related questions were recorded as follows: 0 = *never*, 1 = *rarely* (1 time/mo), 2 = *sometimes* (2–4 times/mo), 3 = *often* (5–15 times/mo), and 4 = *almost always* (16–30 times/mo).

Sleep duration was determined using the question, “How much sleep do you usually get at night on weekdays or workdays?” The response was recorded as the number of hours of sleep obtained on a typical night, which was assessed as a continuous variable.

Covariates—The covariates included the respondent’s age, sex, education, race/ethnicity, educational level, income (in dollars), marital status, exercise (min/d), body mass index recorded in kg/m², access to health insurance, general health, mental health (number of days of poor mental health in the past month), anxiety (number of days feeling anxious or worried in the past month), and depression (measured using Patient Health Questionnaire [PHQ-9]). All data except for mental health and depression were gathered during the in-home interview phase of the survey. Data on mental health and depression were obtained using computer-assisted personal interviews [30,31].

Statistical analysis—Two-year full sample weights were used to adjust for unequal probability of being selected among non-coverage or non-response population, as recommended [32]. Complete case analyses and frequency-weighting schemes were conducted to generalize our findings, as recommended previously [26]. The responses to the three questions regarding sleep insomnia and one regarding DS symptoms were dichotomized into “present” versus “absent” based on their distribution. Here, “present” represented the occurrence of a sleep symptom fewer than five times per month in contrast to “absent” which defined a frequency of fewer than five times per month. Analyses of variance were used to evaluate for differences between the participants based on their habitual caffeine consumption categories. Binomial logistic regression analyses assessed the relationships between the three insomnia symptoms (DFA, DSA, and NRS) and DS (dependent variables) and caffeine consumption variables (independent variables), after adjusting for sociodemographic and health-related covariates. Exploratory interactive models evaluated for two-way interactions between caffeine consumption and sleep duration in predicting insomnia symptoms or DS.

Results

Participant characteristics

The mean $\pm$ SD age of the study population was 46.3 ± 16.4 y. About 51.6% of the sample consisted of women, 71% were white, and 29.5% had some college education. The mean $\pm$ SD caffeine consumption was 176.6 ± 201 mg. Among caffeine users, 43% were moderate to heavy caffeine users with a caffeine consumption of 304.8 ± 196 mg/d, whereas, 46.7% were light caffeine users with a use of 53.5 ± 39.3 mg/d. Those with moderate to heavy caffeine consumption were more likely to be older, male, white, married, and in the highest household income category ($>\$75,000$; Table 1).

Sleep symptoms

Individual insomnia symptoms were prevalent in 19.1% to 28.4% of the respondents, whereas DS was prevalent in 18.6% of the respondents. Their mean $\pm$ SD hours of habitual sleep duration was 6.8 ± 1.4 . There was no difference in the sleep-related variables (insomnia, DS, or sleep duration) across caffeine consumption categories (Table 1).

Bivariate associations

Caffeine consumption.—In unadjusted models, DFA, DSA, and NRS were associated with greater caffeine use. Once these models were adjusted for covariates, these associations were not seen, although a trend toward significance was demonstrated for higher caffeine consumption being associated with DSA. In a single covariate model, race/ethnicity and anxiety symptoms independently attenuated the association of caffeine on DSA. However, on exclusion of race/ethnicity from the multivariable model, the association of caffeine use on DSA reached significance ($P = 0.021$). Similar findings were observed in a model that evaluated the association of caffeine consumption with NRS. When race/ethnicity and anxiety symptoms were excluded as a covariate from the model, the association between caffeine consumption and NRS was significant ($P = 0.006$). In other words, race/ethnicity and anxiety symptoms were the underlying variables responsible for the relationship between caffeine consumption and insomnia symptoms. No association between caffeine consumption and DS existed in either the unadjusted or the adjusted model. When the relationships between sleep variables and the categorical caffeine consumption variable (heavy, light, none) were evaluated, no significant associations were observed (Table 2).

Sleep duration.—Sleep duration was inversely associated with all the insomnia symptoms as well as with DS in the unadjusted and adjusted models (all $P < 0.0005$; Table 2).

Interaction effects—In the unadjusted as well as the adjusted models, a significant interactive effect of caffeine consumption on sleep duration was associated with NRS. In other words, a higher caffeine consumption in conjunction with lower habitual sleep duration was associated with a higher probability of reporting NRS (see Fig. 2).

Discussion

Despite the independent associations of insomnia symptoms with caffeine consumption and sleep duration in prior investigations, no study has evaluated their interactive effects at the population level. In this analysis, we primarily investigated for an association between insomnia symptoms and caffeine consumption. On a secondary basis, we looked for an association between insomnia symptoms and caffeine consumption on habitual sleep duration in a population sample. As expected, sleep duration demonstrated a robust but inverse relationship with insomnia symptoms. However, association of caffeine consumption with insomnia symptoms was not significant in the adjusted models. Furthermore, an interaction of higher caffeine consumption with lower habitual sleep duration was associated with a higher probability of NRS.

The inverse relationship between habitual sleep duration and insomnia symptoms in this study is in line with findings from previous studies. Prior epidemiologic studies have shown that insomnia symptoms such as difficulty of falling asleep or staying asleep and waking up too early or too tired are associated with abnormalities of sleep duration, especially short sleep duration [33–35].

In the unadjusted models, significant associations were seen between caffeine consumption and all the insomnia symptoms. These findings are similar to those in prior studies where regular caffeine use decreased subjective sleep quality and increased sleep latency along with abnormal polysomnographic findings such as decreased slow wave sleep, increased sleep fragmentation, and a resultant reduced sleep duration [10,13,14,16,18]. Interestingly, the relationship between caffeine consumption and insomnia symptoms disappeared once the model was adjusted for covariates. The underlying covariates that were primarily responsible for this relationship were race/ethnicity and anxiety symptoms. In other words, a higher caffeine consumption was seen in those who self-identified as white and those with higher anxiety symptoms over the past month. Prior research has demonstrated relationships between increased caffeine consumption and white respondents [25,36], and also between caffeine consumption and anxiety [9].

Caffeine use has been linked with insufficient sleep duration [2,37]. Its use as a stimulant during the day may disrupt sleep at night and consequently affects alertness the following day. This vicious cycle may result in more caffeine intake, including during the latter part of the circadian day, to achieve the alertness [38]. One factor complicating this relationship is the chronicity of caffeine use. Acute ingestion of caffeine results in shortened sleep on the same or consecutive nights [10,14,16,18]. However, chronic caffeine use may lead to fewer sleep-related complaints in users [12]. This use of caffeine, especially in middle-aged adults, as seen here and previously [13,15], may make users vulnerable to the circadian wake-promoting signal during daytime and also lead to sleep fragmentation [16]. Sleep fragmentation may be clinically manifested as NRS. In light of this information, it is not surprising to see this association between NRS and an interaction of higher caffeine consumption with lower habitual sleep duration, as seen in the present study.

Despite the uniqueness of these results, several limitations should be considered while interpreting them. The cross-sectional nature of the study prevents us from establishing a cause and effect between the different variables. The self-reported sleep symptoms are not validated, but have been used to assess sleep disorders based on previous published research [33,39–42]. Caffeine intake was obtained from in-person interviews on 24-h dietary information of participants to minimize recall bias. The lack of proper psychometric instruments on conditions such as mood disorders and personality disorders entails cautious interpretation of the significant associations.

Another limitation is the information missing at random due to non-responses on sleep measures and covariates. The sensitivity analyses showed no differences on sleep outcomes but significant differences in covariates that may have resulted in bias estimates. The self-report measure of sleep duration may not correlate other subjective measures or with in-laboratory sleep measures, as shown previously [19]. It is possible that a fraction of these respondents had different sleep duration on weekdays than on weekends, and consequently this led to fluctuations in their insomnia symptoms and caffeine consumption through the week. The reported association of high caffeine use with psychiatric disorders and insomnia may confound our association [43–47]. Alternatively, an increase in insomnia symptoms due to excess caffeine may potentially aggravate preexisting disorders [43]. The finding of an increase in insomnia symptoms with insufficient sleep and higher caffeine intake can help us understand this latter relationship. However, the limited NHANES data on the psychiatric information, or related medications, prevented us from exploring these relationships further [48]. The assessment of psychiatric disorders at the population level is another unique challenge, and warrants further research.

Despite these limitations, the present study is one of the first to assess the complex relationships between caffeine consumption and sleep-related complaints at a population level. Future studies should probe this relationship further for daily variations in sleep duration, insomnia symptoms, and caffeine consumption through the week and with objective measures for caffeine consumption and sleep.

Conclusion

Daily caffeine use is associated with insomnia symptoms at the community level, and this relationship can be explained by underlying anxiety levels and differences in race/ethnicity of the participants. A positive interaction between insufficient sleep and higher caffeine consumption was associated with a higher risk for NRS. The complex relationship between caffeine consumption and insomnia symptoms is affected by sleep and other variables at a population level.

Acknowledgment

The authors acknowledge Chris Rjepaj for help with the preparation of this manuscript.

This study was supported by Veterans Affairs grants IK2 CX000855 (SC), K23 HL110216, 12 SDG9180007, R01 AT003332, R01 MH077900 and the University of Pennsylvania grant CTSA UL1 RR024134. The content of this publication does not represent the views of the Department of Veterans Affairs, the US government, the University of Pennsylvania, or any other participating institution. The research hypotheses were conceptualized by MAG and

SC. The data analysis was conducted by NJ. The manuscript was drafted by NSC, in coordination with MAG, SC, and NJ. All authors approved the final version of the manuscript. The authors have no conflicts of interest to declare.

References

- [1]. Malinauskas BM, Aeby VG, Overton RF, Carpenter-Aeby T, Barber-Heidal K. A survey of energy drink consumption patterns among college students. *Nutr J* 2007;6:35. [PubMed: 17974021]
- [2]. Centers for Disease Control. Energy drink consumption and its association with sleep problems among U.S. service members on a combat deployment –Afghanistan, 2010. *MMWR Morb Mortal Wkly Rep* 2012;61:895–8. [PubMed: 23134972]
- [3]. Lieberman HR, Wurtman RJ, Emde GG, Roberts C, Coviella IL. The effects of low doses of caffeine on human performance and mood. *Psychopharmacology* 1987;92:308–12. [PubMed: 3114783]
- [4]. Newman RA, Kamimori GH, Wesensten NJ, Picchioni D, Balkin TJ. Caffeine gum minimizes sleep inertia. *Percept Mot Skills* 2013;116:280–93. [PubMed: 23829154]
- [5]. McLellan TM, Bell DG, Kamimori GH. Caffeine improves physical performance during 24 h of active wakefulness. *Aviat Space Environ Med* 2004;75:666–72. [PubMed: 15328782]
- [6]. McLellan TM, Kamimori GH, Bell DG, Smith IF, Johnson D, Belenky G. Caffeine maintains vigilance and marksmanship in simulated urban operations with sleep deprivation. *Aviat Space Environ Med* 2005;76:39–45. [PubMed: 15672985]
- [7]. McLellan TM, Kamimori GH, Voss DM, Bell DG, Cole KG, Johnson D. Caffeine maintains vigilance and improves run times during night operations for Special Forces. *Aviat Space Environ Med* 2005;76:647–54. [PubMed: 16018347]
- [8]. McLellan TM, Kamimori GH, Voss DM, Tate C, Smith SJ. Caffeine effects on physical and cognitive performance during sustained operations. *Aviat Space Environ Med* 2007;78:871–7. [PubMed: 17891897]
- [9]. Omvik S, Pallesen S, Bjorvatn B, Thayer J, Nordhus IH. Night-time thoughts in high and low worriers: reaction to caffeine-induced sleeplessness. *Behav Res Ther* 2007;45:715–27. [PubMed: 16949554]
- [10]. Calamaro CJ, Mason TB, Ratcliffe SJ. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. *Pediatrics* 2009;123:e1005–10. [PubMed: 19482732]
- [11]. Karacan I, Thornby JI, Anch M, Booth GH, Williams RL, Salis PJ. Dose-related sleep disturbances induced by coffee and caffeine. *Clin Pharmacol Ther* 1976;20:682–9. [PubMed: 186223]
- [12]. Bonnet MH, Arand DL. Caffeine use as a model of acute and chronic insomnia. *Sleep* 1992;15:526–36. [PubMed: 1475567]
- [13]. Brezinova V. Effect of caffeine on sleep: EEG study in late middle age people. *Br J Clin Pharmacol* 1974;1:203–8. [PubMed: 22454948]
- [14]. Shilo L, Sabbah H, Hadari R, Kovatz S, Weinberg U, Dolev S, et al. The effects of coffee consumption on sleep and melatonin secretion. *Sleep Med* 2002;3:271–3. [PubMed: 14592218]
- [15]. Salin-Pascual RJ, Valencia-Flores M, Campos RM, Castano A, Shiromani PJ. Caffeine challenge in insomniac patients after total sleep deprivation. *Sleep Med* 2006;7:141–5. [PubMed: 16459138]
- [16]. Carrier J, Paquet J, Fernandez-Bolanos M, Girouard L, Roy J, Selmaoui B, et al. Effects of caffeine on daytime recovery sleep: a double challenge to the sleep-wake cycle in aging. *Sleep Med* 2009;10:1016–24. [PubMed: 19342294]
- [17]. Drake CL, Jefferson C, Roehrs T, Roth T. Stress-related sleep disturbance and polysomnographic response to caffeine. *Sleep Med* 2006;7:567–72. [PubMed: 16996309]
- [18]. LaJambe CM, Kamimori GH, Belenky G, Balkin TJ. Caffeine effects on recovery sleep following 27 h total sleep deprivation. *Aviat Space Environ Med* 2005;76:108–13. [PubMed: 15742825]

- [19]. Grandner MA, Patel NP, Gehrman PR, Perlis ML, Pack AI. Problems associated with short sleep: bridging the gap between laboratory and epidemiological studies. *Sleep Med Rev* 2010;14:239–47. [PubMed: 19896872]
- [20]. Hicks RA, Hicks GJ, Reyes JR, Cheers Y. Daily caffeine use and the sleep of college students. *Bull Psychon Soc* 1983;21:24–5.
- [21]. Anund A, Kecklund G, Peters B, Akerstedt T. Driver sleepiness and individual differences in preferences for countermeasures. *J Sleep Res* 2008;17:16–22. [PubMed: 18275551]
- [22]. Sanchez-Ortuno M, Moore N, Taillard J, Valtat C, Leger D, Bioulac B, et al. Sleep duration and caffeine consumption in a French middle-aged working population. *Sleep Med* 2005;6:247–51. [PubMed: 15854855]
- [23]. Roth T. Insomnia: definition, prevalence, etiology, and consequences. *J Clin Sleep Med* 2007;3:S7–10. [PubMed: 17824495]
- [24]. 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* 2000;149:203–16. [PubMed: 10823400]
- [25]. Pomeranz JL, Munsell CR, Harris JL. Energy drinks: an emerging public health hazard for youth. *J Public Health Policy* 2013;34:254–71. [PubMed: 23486464]
- [26]. Centers for Disease Control Prevention. National Health and Nutrition Examination Survey Data Analytic Guidelines, 1999–2010. Hyattsville, MD: CDC; 2013.
- [27]. Tinley EM, Durlach PJ, Yeomans MR. How habitual caffeine consumption and dose influence flavour preference conditioning with caffeine. *Physiol Behav* 2004;82:317–24. [PubMed: 15276794]
- [28]. Mackay M, Tiplady B, Scholey AB. Interactions between alcohol and caffeine in relation to psychomotor speed and accuracy. *Hum Psychopharmacol* 2002;17:151–6. [PubMed: 12404692]
- [29]. Benowitz NL. Clinical pharmacology of caffeine. *Annu Rev Med* 1990;41:277–88. [PubMed: 2184730]
- [30]. Centers for Disease Control Prevention. National Health and Nutrition Examination Survey: Plan and Operations, 1999–2010. Hyattsville, MD: CDC; 2013.
- [31]. Kroenke K, Spitzer RL. The PHQ-9: a new depression diagnostic and severity measure. *Psychiatr Ann* 2002;32:509–15.
- [32]. Centers for Disease Control Prevention. National Health and Nutrition Examination Survey Data, 2007–2008. Hyattsville, MD: CDC; 2010.
- [33]. Grandner MA, Kripke DF. Self-reported sleep complaints with long and short sleep: a nationally representative sample. *Psychosom Med* 2004;66:239–41. [PubMed: 15039509]
- [34]. Mesas AE, Lopez-Garcia E, Leon-Munoz LM, Graciani A, Guallar-Castillon P, Rodriguez-Artalejo F. The association between habitual sleep duration and sleep quality in older adults according to health status. *Age Ageing* 2011;40:318–23. [PubMed: 21330338]
- [35]. Racine C, Kalra K, Ceide M, Williams NJ, Zizi F, Mendlowicz MV, et al. Sleep duration, insomnia symptoms, and emotion regulation among black women. *J Sleep Disord Ther* 2013;2:1–6.
- [36]. Lieberman HR, Stavinoha T, McGraw S, White A, Hadden L, Marriott BP. Caffeine use among active duty US army soldiers. *J Acad Nutr Diet* 2012;112:902–12. 912 e1–4. [PubMed: 22709816]
- [37]. Seicean A, Redline S, Seicean S, Kirchner HL, Gao Y, Sekine M, et al. Association between short sleeping hours and overweight in adolescents: results from a US suburban high school survey. *Sleep Breath* 2007;11:285–93. [PubMed: 17440761]
- [38]. Wesensten NJ. Legitimacy of concerns about caffeine and energy drink consumption. *Nutr Rev* 2014;72(Suppl 1):78–86. [PubMed: 25293547]
- [39]. Chakravorty S, Jackson N, Chaudhary N, Kozak PJ, Perlis ML, Shue HR, et al. Daytime sleepiness: associations with alcohol use and sleep duration in Americans. *Sleep Disord* 2014;2014:959152. [PubMed: 24672731]
- [40]. Grandner MA, Jackson N, Gerstner JR, Knutson KL. Sleep symptoms associated with intake of specific dietary nutrients. *J Sleep Res* 2014;23:22–34. [PubMed: 23992533]

- [41]. Grandner MA, Petrov ME, Rattanaumpawan P, Jackson N, Platt A, Patel NP. Sleep symptoms, race/ethnicity, and socioeconomic position. *J Clin Sleep Med* 2013;9:897–905. [PubMed: 23997702]
- [42]. Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, et al. Short sleep duration as a risk factor for hypertension: analyses of the first National Health and Nutrition Examination Survey. *Hypertension* 2006;47:833–9. [PubMed: 16585410]
- [43]. Guo X, Park Y, Freedman ND, Sinha R, Hollenbeck AR, Blair A, et al. Sweetened beverages, coffee, and tea and depression risk among older US adults. *PLoS One* 2014;9:e94715. [PubMed: 24743309]
- [44]. Ishak WW, Ugochukwu C, Bagot K, Khalili D, Zaky C. Energy drinks: psychological effects and impact on well-being and quality of life-a literature review. *Innov Clin Neurosci* 2012;9:25–34.
- [45]. Lara DR. Caffeine, mental health, and psychiatric disorders. *J Alzheimers Dis* 2010;20(Suppl 1):S239–48. [PubMed: 20164571]
- [46]. Pigeon WR, Pinquart M, Conner K. Meta-analysis of sleep disturbance and suicidal thoughts and behaviors. *J Clin Psychiatry* 2012;73: e1160–7. [PubMed: 23059158]
- [47]. Pompili M, Innamorati M, Forte A, Longo L, Mazzetta C, Erbuto D, et al. Insomnia as a predictor of high-lethality suicide attempts. *Int J Clin Pract* 2013;67:1311–6. [PubMed: 24246209]
- [48]. Reeves WC, Strine TW, Pratt LA, Thompson W, Ahluwalia I, Dhingra SS, et al. Mental illness surveillance among adults in the United States. *MMWR* 2011;60:1–29.

Fig. 1.

Overview of study population. *Missing values overlap across variables. †Total missing sample (n = 1498). NHANES, National Health and Nutritional Examination Survey.

Fig. 2. Surface plot representing interaction of caffeine on sleep duration in predicting NRS. NRS, nonrestorative sleep.

Characteristics for the total sample as well as stratified by caffeine consumption status

Table 1

Characteristic	Subgroup	Total sample (N = 4730)	Caffeine consumption status*			P-value
			None (n = 461)	Light (n = 2212)	Mod-heavy (n = 2057)	
Age, y, mean (SD)	-	46.3 (16.4)	41.2 (18.6)	45.1 (18.7)	48.2 (13.9)	<0.001
Sex (%)	Female	51.6	51.8	56.6	47.5	<0.001
Race/ethnicity (%)	Non-Hispanic White	71.0	46.5	61.4	82.7	<0.001
	Hispanic	12.9	18.3	18.2	7.8	<0.001
	Non-Hispanic black	10.9	24.8	15.4	5.1	<0.001
Marital status (%)	Other	5.2	10.4	5	4.5	<0.001
	Married	56.8	45.4	52.5	62	<0.001
	Widowed	5.3	3.8	6.2	4.8	<0.001
	Divorced	10.5	9.8	8.8	12.0	<0.001
	Separated	2.5	3.3	2.8	2.1	<0.001
	Never married	17.6	29.1	22.0	12.1	<0.001
	Living with partner	7.4	8.6	7.7	7	<0.001
Education (%)	College	26.1	21.4	23.2	29.1	0.039
	< High school	19.6	26.0	20.7	17.7	0.039
	High school graduate	24.8	22.2	25.6	24.6	0.039
	Some college	29.5	30.4	30.5	28.6	0.039
Annual household income (%)	<\$35,000	33.6	41.7	37.6	29.1	<0.001
	\$35,000-\$55,000	18	20	19	16.8	<0.001
	\$55,000-\$75,000	14.7	12.6	13.8	15.7	<0.001
	>\$75,000	33.8	25.8	29.6	38.5	<0.001
General health (%)	Excellent	17.2	18	16.6	17.5	0.637
	Good to very good	65.4	62.2	65.5	65.9	0.637
	Poor to very poor	17.4	19.8	18	16.6	0.637
Health insurance n (%)	Uninsured	18.9	23.0	21.9	15.8	<0.001
Depression [†] (%)	Not at all	75.9	79.3	75.9	75.4	0.676
	Several days	17.5	15.6	17.4	17.9	0.676

Characteristic	Subgroup	Total sample (N = 4730)	Caffeine consumption status*			P-value
			None (n = 461)	Light (n = 2212)	Mod-heavy (n = 2057)	
	More than half	3.5	2.1	3.6	3.7	0.676
	Nearly every day	3.1	3	3.1	3	0.676
BMI kg/m ² , mean (SD)	-	28.7 (6.7)	29.1 (8.9)	28.7 (7.2)	28.7 (5.9)	0.875
Exercise, min/d, mean (SD)	-	165.2 (220.7)	164.1 (232.5)	158.6 (239.7)	170.8 (202.4)	0.354
Anxiety [‡] , mean (SD)	Days in past mo	5.5 (9)	4.3 (8.6)	5.1 (9.1)	6 (8.7)	0.039
Poor MH mean (SD)	Days in past mo	3.9 (7.8)	4 (8.9)	3.6 (7.9)	4.1 (7.4)	0.063
Caffeine, mg, mean (SD)	-	176.6 (201)	-	53.5 (39.3)	304.8 (196)	-
DFA (%)	Present	19.1	15.5	19.3	19.5	0.473
DSA (%)	Present	21	17.4	20.1	22.2	0.161
NRS (%)	Present	28.4	25	27.2	29.9	0.316
DS (%)	Present	18.6	16.1	18.3	19.2	0.618
Sleep duration (%)	Hours	6.8 (1.4)	6.8 (1.6)	6.9 (1.5)	6.8 (1.2)	0.134

BMI, body mass index; DFA, difficulty falling asleep; DS, daytime sleepiness; DSA, difficulty staying asleep; MH, mental health; NRS, non-restorative sleep

* Light caffeine use, 120 mg/d; mod-heavy consumption, >120 mg/d.

[‡] Depression = feeling depressed in the last 2 wk.

[‡] Anxiety = days anxious over the past month.

Table 2
Bivariate associations (unadjusted and adjusted) of caffeine and sleep duration with sleep disorder outcomes

Predictor Variable, unit	Sleep variables					
	DFA		DSA		NRS	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Unadjusted models (bivariate models)						
Caffeine use, mg [*]	1.09 (1.02–1.17)	0.006	1.11 (1.05–1.18)	<0.001	1.12 (1.03–1.21)	0.005
Sleep duration/l h	0.590 (0.55–0.65)	< 0.001	0.60 (0.56–0.64)	< 0.001	0.68 (0.62–0.74)	< 0.001
Models adjusted for covariates (multivariable models) [†]						
Caffeine use, mg [*]	1.06 (0.97–1.16)	0.178	1.07 (0.99–1.15)	0.075	1.06 (0.97–1.15)	0.155
Sleep duration/l h	0.60 (0.56–0.65)	< 0.001	0.60 (0.56–0.65)	< 0.001	0.68 (0.62–0.74)	< 0.001
Analysis of interactions						
Interaction term	DFA (<i>P</i> -value)		DSA (<i>P</i> -value)		NRS (<i>P</i> -value)	DS (<i>P</i> -value)
Unadjusted model						
Caffeine use [‡] sleep duration	0.395		0.108		0.013	0.301
Models adjusted for covariates [‡]						
Caffeine use [‡] sleep duration	0.567		0.101		0.008	0.284

DFA, difficulty falling asleep; DSA, difficulty staying asleep; NRS, nonrestorative sleep; DS, daytime sleepiness Bold P values indicate statistically significant associations.

^{*} In terms of a SD increase.

[†] Models adjusted for Adjusted for age, sex, race/ethnicity, education, income, marital status, exercise, body mass index, access to health insurance, physical health, mental health, depression, and anxiety.

[‡] Denotes interaction between terms.