Caffeine Intake from Food and Beverage Sources and Trends among Children and Adolescents in the United States: Review of National Quantitative Studies from 1999 to 2011[1–5]

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ABSTRACT

There is increasing concern about potential adverse effects of caffeine in children. Our understanding of caffeine intake relies on studies dating to the late 1990s. This article synthesizes information from national studies since then to describe caffeine consumption, its association with sociodemographic factors, key dietary sources including caffeine-containing energy drinks (CCEDs), and trends in caffeine intake and sources among US children. Findings from the Kanter Worldpanel (KWP) Beverage Consumption Panel and the NHANES showed that caffeine consumption prevalence was generally consistent across studies and over time; more than one-half of 2- to 5-y-olds and ~75% of older children (>5 y) consumed caffeine. The usual intakes of caffeine were 25 and 50 mg/d for children and adolescents aged 2–11 and 12–17 y, respectively (NHANES 2007–2010). Caffeine consumption correlated with age and was higher in non-Hispanic white children. The key sources of caffeine were soda and tea as well as flavored dairy (for children aged <12 y) and coffee (for those aged ≥12 y). The frequency of CCED use varied (2–30%) depending on study setting, methods, and demographic characteristics. A statistically significant but small decline in caffeine intake was noted in children overall during the 10- to 12-y period examined; intakes remained stable among older children (≥12 y). A significant increasing trend in CCED and coffee consumption and a decline in soda intake were noted (1999–2010). In 2009–2010, 10% of 12- to 19-y-olds and 10–25% of caffeine consumers (aged 12–19 y) had intakes exceeding Canadian maximal guidelines. Continued monitoring can help better understand changes in caffeine consumption patterns of youth. *Adv Nutr* 2015;6:102–111.

Keywords: caffeine intake, dietary sources, children, adolescents, trends

Introduction

Caffeine is a stimulant frequently consumed by adults and children (1, 2). It is present in foods and beverages and occurs naturally or as an additive. Caffeine consumption by children and adolescents has been the subject of considerable attention because of the concern about potential adverse health effects. Caffeine intake between 100 and 400 mg has been associated with increased reports of nervousness, jitteriness, and fidgetiness (3, 4). Because of continued brain development involving myelination and pruning processes, children are considered to be particularly sensitive to caffeine (5, 6). There is some evidence that caffeine intake in children and young persons is associated with sleep dysfunction, impairments in mineral absorption and bone health, elevated blood pressure, and increased alcohol use/dependence (3, 7–9). The routine use of caffeine as part of sugar-sweetened beverages may contribute to weight gain and dental cavities (10). Caffeine toxicity in children has also been described and involves central nervous system agitation, tachycardia, gastrointestinal disturbance, nausea, and diuresis (8, 11, 12). On the other hand, caffeine consumption is also associated with certain health benefits including increased attention, mental alertness, concentration, endurance, and athletic performance (2, 8, 11, 13, 14).

Traditionally, carbonated soft drinks, tea, and coffee have been the chief contributors of caffeine intake in children

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(15). However, in recent decades, specialty drinks, caffeine-containing energy drinks (CCEDs)[6], and energy shots have been introduced in the market, some specifically targeted to youth. CCEDs may contain 1- to 4-fold greater amounts of caffeine than soft drinks (sodas; 24.0–46.4 mg/8 fluid ounces) (16, 17). In comparison, the caffeine content of coffee and specialty coffee beverages is usually much higher (up to 25 times) than carbonated soft drinks depending on the preparation method (16). Caffeine consumption patterns and food and beverage sources of caffeine among children and youth may have shifted over this past decade because of these changes in the marketplace, related sociocultural factors such as peer pressure, as well as perceived and demonstrated benefits of caffeine (e.g., increased attention, physical performance). In addition, reports of energy drink–related emergency room visits and toxicities have fueled interest in this topic, particularly because most cases concern children (18).

According to the FDA, a caffeine content of 0.02% (200 parts per million) is generally recognized as safe (GRAS) for use in cola-type beverages (19, 20). There are no specific guidelines for caffeine intake in the United States. However, the American Academy of Pediatrics states that "caffeine and other stimulant substances contained in energy drinks have no place in the diet of children and adolescents" (21). Canada has set population recommendations suggesting maximum caffeine intakes. These are 45, 62.5, and 85 mg/d for children aged 4–6, 7–9, and 10–12 y, respectively (22); for teens ≥13 y, Health Canada advises that caffeine intake not exceed 2.5 mg · kg body weight^{-1} · d^{-1}.

The available literature on caffeine intakes and its chief sources among US children and adolescents until recently relied heavily on studies dating to the early 1990s. Barone and Roberts (1) summarized caffeine intakes from various consumption surveys and reported that for caffeine consumers <18 y of age, the mean daily intake was 1 mg/kg body weight; the majority (>95%) of caffeine intake was from caffeinated beverages. Frary et al. (15) described caffeine intake on the basis of USDA Continuing Survey of Food Intakes in Individuals data from 1994 to 1996 and 1998. Based on the average of 2 d of dietary data, caffeine intake among caffeine consumers varied between 16 (for children aged 2–5 y) and 80 (for boys aged 12–17 y) mg/d; corresponding estimates for these age groups in relation to body weight were 0.4–0.6 mg/kg. Knight et al. (23) reported national estimates of mean caffeine intake from beverage sources only on the basis of 14-d records from the 1999 Share of Intake Panel survey (50% response rate). For children and adolescents aged 1–5, 6–9, 10–14, and 15–19 y, mean caffeine intakes were 14, 22, 33, and 66 mg/d, respectively; corresponding 90th percentiles were 37, 45, 74, and 148 mg/d, respectively. Thus, at the turn of this century, this study already highlighted that heavy consumers (caffeine consumption above the 90th percentile) (1, 24) may be exceeding recommended maximal amounts of intake by Health Canada (22). The objective of this article was to review findings from national quantitative studies based on data that have become available since 2000. Specifically, caffeine intakes among US children and adolescents aged 2–19 y, in absolute amounts (mg/d) as well as in relation to body weight (mg · kg^{-1} · d^{-1}) and by sociodemographic factors, are described. The key food and beverage sources contributing to caffeine intake, including CCEDs and energy shots, are also discussed on the basis of published findings as well as new analyses that we conducted using the most recent dietary data available at that time from the NHANES 2009–2010 to describe key sources of caffeine on the basis of the What We Eat in America (WWEIA) food categories (25). In addition, trends in caffeine consumption and in the key foods and beverage sources of caffeine in US youth are presented.

Current Status of Knowledge

The resurgence of interest in caffeine consumption has led to the publication of more timely and comprehensive data on caffeine intakes in the past decade and to scientific conferences on caffeine intake and sources in 2013. A recent report from the FDA presented findings on caffeine consumption based on data from NHANES 2005–2006 and other surveys (26). The FDA also contracted with the Institute of Medicine to hold a public scientific meeting in August 2013 that focused on the safety of caffeine in food and supplements in which data on caffeine exposure, safety, and adverse events were presented (27). In addition, the Office of Dietary Supplements, NIH, held a workshop entitled "The Use and Biology of Energy Drinks: Current Knowledge and Critical Gaps" in August 2013. Since then, nationally representative findings on caffeine intake from food and beverage sources as well as trends in caffeine intake over time have been published (16, 28–30).

Two chief surveys provide key sources of newer quantitative data on caffeine intake of US children since 1999–2000. They are the Kantar Worldpanel (KWP) Beverage Consumption Panel (formerly the Share of Intake Panel); and the continuous NHANES, which monitors the nation's nutrition and health; data from NHANES are publicly released in 2-y cycles.

The KWP syndicated beverage consumption survey involves a representative sample and provides population-based estimates of beverage consumption collected from October 2010 to September 2011 by using a 7-d diary recorded by participants over the Internet (16). Parents reported data for children 2–12 y of age (16). Respondents recorded type, brand, preparation, location (home or away from home), and amount of all beverages consumed over a 7-d period. Information on height, weight, and demographic characteristics was collected at the same time. Notably, findings were reported for consumers of caffeinated beverages only, and several exclusion criteria were applied in the analysis. Children with reports of <21 total beverage occasions, with body weights less than the 3rd or above the 97th percentile based on weight for age, and with fluid intakes >2 SDs were excluded. Only English-speaking participants were included, and there were no exclusions on the basis of questions or health conditions. The response rate was

[6] Abbreviations used: CCED, caffeine-containing energy drink; FNDDS, Food and Nutrient Database for Dietary Studies; KWP, Kantar Worldpanel Beverage Consumption Panel; MEC, mobile examination center; PIR, poverty-income ratio; WWEIA, What We Eat in America.

low (~15%) (Table 1). Caffeine intake from beverages was determined by using a database developed for the survey that combined information from federal databases such as the USDA Food and Nutrient Database for Dietary Studies (FNDDS), version 4.1; the USDA National Nutrient Database for Standard Reference 24; and information obtained from food and beverage companies to obtain brand-specific content when possible (16).

NHANES is a series of large, complex, stratified, multistage probability surveys of the US civilian, noninstitutionalized population, conducted by the National Center for Health Statistics, CDC (31). Since 1999, NHANES has been conducted annually and data are publicly released every 2 y for ~10,000 individuals. Participants are administered a series of questionnaires in a detailed in-home interview, followed by a visit to the mobile examination center (MEC) where participants receive a physical examination and complete a dietary interview. The type and quantity of all foods and beverages consumed in the 24-h period the day before the dietary interview (from midnight to midnight) are collected by trained interviewers using a computer-assisted dietary interview system with standardized probes (i.e., the USDA's Automated Multiple-Pass Method). For beverages where caffeine may be removed, such as soda, coffee, tea, and energy drinks, probes are used to ascertain if the beverage reported was caffeine free. The Automated Multiple-Pass Method is designed to enhance complete and accurate data collection while reducing respondent burden (32, 33). Furthermore, data from a second dietary recall obtained 3–10 d after the MEC visit over telephone by trained dietary interviewers have been publicly available since 2003.

Proxies, generally parents, provide answers for children aged ≤5 y and assist with the dietary interviews of children aged 6–11 y at the MEC. Participants aged ≥12 y self-report their 24-h recall to trained dietary interviewers at the MEC. The survey collects information on all foods, beverages, and supplements consumed by the participant over the 24-h period (on 2 different days). Although the survey is not designed for assessing intakes of specific foods or components, quantitative assessment of dietary intakes by using an interviewer-administered 24-h recall method by trained dietary interviewers with linkage of those data to the USDA food and nutrient databases (e.g., FNDDS) allows for the assessment of intakes of food, nutrients, and certain bioactive components such as caffeine. Caffeine intake for all foods and beverages (including energy drinks) consumed during the 24-h period was estimated by using the USDA FNDDS 5.0 (34). The basis of nutrient values for foods and beverages, such as energy drinks, is the USDA National Nutrient Database for Standard Reference. The sources of nutrient data for these databases include the scientific literature, data provided by food companies and trade associations, and USDA analytical contracts. A unique strength of the NHANES is that its design involving oversampling of certain race-ethnic groups allows for computation of national-level estimates by race/Hispanic origin. The poverty-income ratio (PIR), an index calculated by dividing family income by a federal poverty threshold specific to family size, is generally used as a proxy for socioeconomic status (35); family income corresponding to 130% of the PIR qualifies for the Supplemental Nutrition Assistance Program and free school meals (36).

At least 3 recent studies (28–30) and a report (26) on caffeine intake were based on NHANES data collected since 1999 (Table 1). Somogyi (26) described findings based on a 24-h recall conducted during the MEC examination in NHANES 2005–2006. Fulgoni (28) estimated usual caffeine intakes in the US population on the basis of NHANES 2007–

TABLE 1 Characteristics of published studies presented[1]

Study (ref) and data source	Study population	Sample size, *n*	Age categories of interest	Dietary data collection method	Response rate, %
Mitchell et al. (16)					
Kantar Worldpanel Beverage Consumption Panel, October 2010–September 2011	Caffeine consumers, ages ≥2 y	37,602	2–5, 6–12, 13–17, and 18–24 y	7 consecutive day online beverage diary	~15
Somogyi (26)					
NHANES, 2005–2006	All respondents, ages ≥2 y	~9500	2–5, 6–11, and 12–19 y	Interviewer-administered single 24-h recall	~77[2]
Fulgoni (28)					
NHANES, 2007–2010	All respondents, ages ≥2 y; caffeine consumers, ages ≥2 y	17,387; 13,923	2–11, 12–17, and 18–29 y	Interviewer-administered 24-h recalls on 2 d	NA
Branum et al. (29)					
NHANES, 1999–2010	Caffeine consumers, ages 2–22 y	NA	2–5, 6–11, 12–16, 17–18, and 19–22 y	Interviewer-administered single 24-h recall	75–80
Ahluwalia et al. (30)					
NHANES, 2009–2010	All respondents, ages 2–19 y; caffeine consumers, ages 2–19 y	3280; 2230	2–5, 6–11, and 12–19 y	Interviewer-administered single 24-h recall	81–88

[1] NA, not available from publication; ref, reference.
[2] Available from: http://www.cdc.gov/nchs/data/nhanes/response_rates_cps/RRT0506MF.pdf.

2010 data using the National Cancer Institute method that takes into account intraindividual variation. Branum et al. (29) and Ahluwalia et al. (30) used the most recent dietary data available from NHANES (2009–2010) at the time of these studies to estimate caffeine intake among US children and adolescents on a given day (day 1 recall obtained at the MEC examination) (**Table 2**). A single 24-h recall is considered sufficient to estimate population means because the effects of random errors associated with dietary recall, including day-to-day variability, are generally assumed to cancel out if days of the week are evenly represented (37). Notable differences between the 2 reports (29, 30) using data from NHANES 2009–2010 stem from the ages examined for "children and adolescents": 2–22 y in the report by Branum et al. (29) vs. 2–19 y in the study by Ahluwalia et al. (30). In addition, Ahluwalia et al. (30) presented medians as point estimates because of the skewed nature of caffeine intake vs. means in other reports. Many investigators also examined the trends in caffeine consumption based on NHANES data over the 10- to 12-y period (28–30). In addition, to identify key contributors of caffeine intake, Branum et al. (29) and Fulgoni (28) grouped foods into common categories for the purpose of their analyses (a posteriori). In 2013, the USDA released 150 WWEIA food categories as consumed (a priori) (25). For the sake of comparison, we carried out new analyses with NHANES 2009–2010 dietary data to identify chief WWEIA food categories contributing to caffeine intake among children; findings from those analyses are also described below. The response rate among children and adolescents aged 2–19 y for the 2009–2010 cycle was 85–87% (Table 1) and was >75% for other studies based on NHANES data, varying between 75% and 88% for 1999–2010 (Table 1).

TABLE 2 Consumers of caffeine in published reports of national studies[1]

Study (ref) and data source	Ages of interest examined, y	*n*	Caffeine consumers, %
Mitchell et al. (16)			
Kantar Worldpanel	2–5	732	43.0
Beverage	6–12	1768	63.0
Consumption	13–17	1772	83.2
Panel, October 2010–September 2011	18–24	1178	85.8
Somogyi (26)			
NHANES, 2005–2006	2–5	NA	NA
	6–11	NA	NA
	12–19	NA	NA
Fulgoni (28)			
NHANES, 2007–2010	2–11	NA	NA
	12–17	NA	NA
Branum et al. (29)			
NHANES, 1999–2010[2]	2–5	NA	62.7 ± 1.1
	6–11	NA	74.8 ± 0.9
	12–16	NA	75.3 ± 0.9
	17–18	NA	75.8 ± 1.2
	19–22	NA	76.8 ± 1.6
Ahluwalia et al. (30)			
NHANES, 2009–2010[2]	2–5	861	58.3 ± 2.4
	6–11	1154	74.9 ± 1.7
	12–19	1265	74.5 ± 2.2

[1] NA, not available from publication; ref, reference.
[2] Values for "Caffeine consumers" are proportions ± SEs (when available).

Caffeine consumption (percentage of consumers) and amounts consumed. Caffeine is commonly consumed by children of all ages (Table 2). Ahluwalia et al. (30) showed that more than one-half of US children aged 2–5 y and 3 in 4 older children (≥6 y) consumed caffeine on a given day on the basis of NHANES 2009–2010 data. The corresponding figures regarding the percentage of children who consumed caffeine from beverages over 7 d in the KWP beverage consumption panel were slightly lower for 2- to 5-y-olds and generally similar in older children. The proportion of children who consumed caffeine increased with age (16, 29, 30). Non-Hispanic black children were less likely to consume caffeine than were non-Hispanic white children consistently across reports (29, 30).

Studies on caffeine intake among children generally report absolute amount consumed (mg) (reviewed in **Table 3**); fewer studies describe caffeine consumption in relation to body weight (mg/kg) (16, 30). Because guidelines for certain age groups are based on milligrams per kilogram (38) it is important to examine caffeine intake in relation to body weight as well. Further complexity in summarizing the literature arises from the fact that studies either report intakes in caffeine consumers only or in all respondents; few provide findings for all participants as well as consumers only (28–30) (Table 3). In addition, most studies present mean intakes of caffeine, even though caffeine consumption shows a right-skewed distribution; these averages/means would be biased (toward higher estimates) because of the influence of extreme values. Median intakes may be a more appropriate reflection of the amounts of caffeine consumed by US children; thus, the report by Ahluwalia et al. (30) provided both means and medians. Although more complex to obtain, usual intake estimates are considered a more precise reflection of the habitual intake because both the intraindividual variation across days surveyed as well as the distribution of the data are taken into account (39, 40). To our knowledge, only 1 study provided the estimates of usual intake based on the National Cancer Institute method (28). There is no reported information on time trends based on usual intakes, and this remains to be examined in future studies as more user-friendly software programs (coding) become available. Most published studies examined trends in caffeine consumption over time on the basis of intakes obtained via a single 24-h recall at each time point (28–30).

The methodologic differences in data collection and/or data analysis make the synthesis of findings on caffeine intake among children challenging. These differences include the following: 1) the use of dietary data from a single day (26, 29, 30), 2 d (28), or 7 d (16); *2*) varying age categories; *3*) stratification by gender; and *4*) caffeine intake determined from beverages only vs. from foods and beverages (16) (Table 2). Studies that reported mean intakes either from beverages only (16) or from both food and beverages (26, 29) generally reported higher estimates of caffeine intake than those based

TABLE 3 Mean caffeine consumption in absolute amounts and in relation to body weight in published reports of national studies[1]

Study (ref) and age group	Caffeine intake			
	Among all respondents, mg/d	Among caffeine consumers only, mg/d	Among all respondents, mg · kg^{-1} · d^{-1}	Among caffeine consumers only, mg · kg^{-1} · d^{-1}
Mitchell et al. (16)[2]				
2–5 y	NA	23.7 ± 1.8	NA	1.5 ± 0.2
6–12 y	NA	36.6 ± 1.2	NA	1.1 ± 0.0
13–17 y	NA	83.2 ± 2.2	NA	1.3 ± 0.0
18–24 y	NA	122.1 ± 4.2	NA	1.7 ± 0.1
Somogyi (26)[3]				
2–5 y	8.4	NA	NA	NA
6–11 y	19.7	NA	NA	NA
12–19 y	69.5	NA	NA	NA
Fulgoni (28)[4]				
2–11 y	25	~40	NA	NA
12–17 y	50	~70	NA	NA
Branum et al. (29)[5]				
2–5 y	5.8 ± 0.4	10.0 ± 1.0	NA	NA
6–11 y	17.2 ± 1.1	23.0 ± 1.4	NA	NA
12–16 y	48.4 ± 8.0	64.3 ± 9.8	NA	NA
17–18 y	69.4 ± 5.9	96.1 ± 7.2	NA	NA
19–22 y	90.3 ± 7.1	116.4 ± 8.4	NA	NA
Ahluwalia et al. (30)[5,6]				
2–5 y	1.3 ± 0.26	4.7 ± 0.52	0.11 ± 0.02	0.29 ± 0.03
6–11 y	4.5 ± 0.69	9.1 ± 0.73	0.15 ± 0.01	0.30 ± 0.02
12–19 y	13.6 ± 2.92	40.6 ± 5.62	0.22 ± 0.05	0.64 ± 0.08

[1] Values are means ± SEs unless otherwise noted. NA, not available from publication; ref, reference.
[2] Caffeine was from beverage sources only.
[3] Estimates in the table are for boys only. Estimates for girls are 6.9, 17.0, and 46.6 mg for girls aged 2–5, 6–11, and 12–19 y, respectively. The study did not provide estimates for boys and girls pooled.
[4] Mean usual intakes were estimated by using the National Cancer Institute method among all respondents.
[5] Estimates are from the NHANES 2009–2010 survey cycle.
[6] Medians ± SEs of caffeine consumption on a given day among all respondents from all food and beverage sources are presented.

on median intakes (30) (Table 3). By using data from NHANES 2009–2010 Ahluwalia et al. (30) found that median caffeine intakes on a given day among US children and adolescents aged 2–5, 6–11, and 12–19 y were 1.3, 4.5, and 14.6 mg, respectively; the corresponding intakes among caffeine consumers only were slightly higher (i.e., 4.7, 9.1, and 40.6 mg, respectively). These estimates were similar to the usual intake estimates of 4.8, 13.8, 31.5, and 79.3 mg/d for ages 1–3, 4–8, 9–13, and 14–18 y, respectively, on the basis of NHANES 2007–2010 data from two 24-h dietary recalls, although the age groups reported were somewhat different (41). For the same years of NHANES 2007–2010, the usual caffeine intakes of US children aged 2–11 and 12–17 y were 25 and 50 mg/d, respectively (28).

Few studies reported on caffeine intake in relation to body weight on the basis of data up to 1999 (1, 15, 23); these estimates were updated in more recent publications (16, 30). Ahluwalia et al. (30) examined caffeine intake expressed in relation to body weight (mg/kg) on a given day on the basis of a single 24-h recall obtained during the MEC visit. The estimates of caffeine intake (mg/kg) among caffeine consumers reported in the study by Ahluwalia et al. were generally lower than previously reported on the basis of older data (1, 15, 23). For instance, Frary et al. (15), whose study was based on older Continuing Survey of Food Intakes in Individuals data, reported daily intakes of 0.4, 0.4, 0.5, and 0.6 mg/kg for children aged 2–5 y, children aged 6–11 y, boys aged 12–17 y, and girls aged 12–17 y, respectively, compared with our estimates of 0.3 mg/kg for children aged 2–5 and 6–11 y. Interestingly, the estimates of caffeine intake from food and beverages by Ahluwalia et al. (30) were also lower than the mean estimates reported by Mitchell et al. (16) from the KWP beverage consumption panel; because of skewed distribution of caffeine intake, mean values may represent an overestimation of central tendency in this population. Overall, our finding of lower estimated caffeine intakes (mg/kg) in more recent NHANES surveys (2009–2010) compared to the older literature is in line with the declining trend in caffeine consumption noted previously by Barone and Roberts (1).

Another limitation in the existing reports is that caffeine intakes from sources such as gum, supplements (energy shots), and medicines (e.g., diet pills, antidrowsiness pills) were not included in most of the studies. In 1 study, the KWP beverage consumption panel, the consumption of energy shots was considered (16); however, their use was rarely reported by the participants. Thus, we conducted post hoc analyses of NHANES 2009–2010 supplement-use data to examine energy shots use in children; our findings confirm that energy shots (considered supplements, thus not included in the FNDDS database) were rarely consumed among children aged 2–19 y. It is important to note that this review was conducted with reports published through September 2014, which relied on data collected up to 2011. Because of market trends showing increased availability and sales of various caffeinated beverages such as energy drinks as well as energy shots since 2010, it is important to re-examine the current consumption patterns in these products, especially among

subgroups likely to consume them such as preteens and teens, as more updated data become available.

Association of caffeine intake with sociodemographic factors. Caffeine intake has been positively associated with age in most studies (16, 26, 28–30), although many studies examined this association in a broad age range including both ends of the age spectrum from young children to older adults. Studies focusing on children and adolescents based on NHANES data from 1999 to 2010 (29) or 2009–2010 (30) reported a positive trend between caffeine intake (mg) and age. In addition, caffeine consumption was not associated with PIR (29, 30). Furthermore, Ahluwalia et al. (30) noted similar findings for the associations of caffeine intake expressed in relation to body weight (mg/kg) with age and PIR. Non-Hispanic black children had lower caffeine intakes (mg or mg/kg) than did non-Hispanic white children consistently across reports based on NHANES 1999–2010 (29) and 2009–2010 data (30). Branum et al. (29) reported that Mexican-Americans aged 2–22 y also consumed less caffeine (mg) than did non-Hispanic white counterparts by using data pooled over 12 y from NHANES (1999–2010). However, Ahluwalia et al. (30) did not note these differences with more recent data from NHANES 2009–2010 among children and adolescents aged 2–19 y. The findings for the association of caffeine intake with sociodemographic factors were essentially similar when analyses were restricted to consumers only (30). In summary, older children (≥12 y) and non-Hispanic white children consumed more caffeine than did their counterparts (i.e., younger children and non-Hispanic blacks, respectively).

Food and beverage sources of caffeine. Carbonated soft drinks, tea, and coffee have been described as the chief contributors of caffeine intake in children (15). Because of the introduction of specialty drinks, CCEDs, and energy shots in the market in the past decades (28), recent studies have examined the contribution of foods and beverages categorized a posteriori into groups for the purposes of analysis (28, 29). These studies used NHANES data from different cycles, 2007–2010 (28) and 1999–2010 (29), to identify chief sources of caffeine in the entire population, in children and adolescents aged 2–11 and 12–17 y (28), and in children and young persons aged 2–22 y (29). Fulgoni (28) reported sodas as the main source of caffeine for both 2–11- and 12–17-y age groups, whereas Branum et al. (29) reported that soda and tea were the major contributors of caffeine for those aged 2–22 y. In addition, flavored dairy emerged as another key source for younger children (2–11 y) and coffee was a chief source as well for those aged 12–22 y. Although the amount of caffeine from flavored dairy was smaller (~17 and 10 mg/d for children aged 2–5 and 6–11 y, respectively), this is equivalent to 33–50% of caffeine from soda or tea for children <12 y of age (29).

Recently, the USDA published 150 WWEIA food categories that describe commonly consumed groups of foods and beverages as consumed, i.e., not disaggregated into their component parts (25). By pairing these categories with the individual food files in NHANES (42) and multiplying the individual's caffeine intake per food item by the individual's sample weight, it is possible to calculate the weighted fractions of the population's intake of caffeine from each of the WWEIA food categories. Thus, for the purpose of this presentation at the Experimental Biology 2014 meeting, we conducted a new analysis based on NHANES 2009–2010 data to compute the caffeine contribution from these WWEIA as-consumed food categories for the sake of comparison with other published approaches. The WWEIA "sports and energy drink" category contains both CCEDs and noncaffeinated energy drinks. Therefore, for our analyses, we kept food codes corresponding to CCEDs only in "sports and energy drinks with caffeine." The population proportions of caffeine contribution from each WWEIA category were then determined as a ratio of means (i.e., the sum of caffeine from each WWEIA category for all persons divided by the sum of caffeine from all foods for all persons in the group of interest) (42).

Our findings from these new analyses showing the major WWEIA categories that contributed to caffeine intake in children and adolescents are presented in **Table 4**. Similar to the results of Fulgoni (28) and Branum et al. (29), we found that carbonated soft drinks (i.e., sodas) and tea were the major sources of caffeine among all age groups examined. Using the WWEIA food categories, we noted that most of the caffeine consumption from soft drinks was from "standard" sodas rather than from diet sodas. In addition, flavored milk (low-fat, reduced-fat, whole) also contributed a large proportion of caffeine intake for younger age groups (2–5 and 6–11 y) (Table 4). For comparison, we grouped the 5 WWEIA-related categories (3 flavored milk categories with varying fat content, milkshakes/other dairy drinks, and ice cream/frozen dairy desserts) into a single category, "flavored dairy." We also combined the WWEIA categories "cookies and brownies" and "cakes and pies" into a single category ("cookies and cakes"). **Figure 1** shows the key food/beverage sources of caffeine in children by age group from the WWEIA-based food categories. Our findings are consistent with those of Branum et al. (29) and highlight soda, tea, and flavored dairy as key contributors of caffeine in children aged <12 y and soda, tea, and coffee as chief sources of caffeine in older children.

Because of the special focus and potential concerns related to energy drink consumption, we also examined the contribution of energy drinks to caffeine intake among children and adolescents from recently published findings that were based on data collected up to 2011 (**Table 5**). The studies based on NHANES or KWP beverage consumption panel summarized in Table 5 show that energy drinks were not a key source of caffeine among US children and adolescents. On the basis of our analyses, consumption of energy drinks and their contribution to caffeine intake were negligible for children <12 y of age, and for those aged 12–19 y caffeinated energy drinks provided ~4.4% of the total caffeine intake on a given day (Table 4, Figure 1). Likewise, on the basis of 2001–2010 data from NHANES, Fulgoni (28) also reported that energy drinks contribute little to caffeine intake

TABLE 4 Percentage contribution of the WWEIA food and beverage categories to caffeine intake by age group: findings from analyses of NHANES 2009–2010 data[1]

WWEIA food and beverage categories	2–5 y (*n* = 861)	6–11 y (*n* = 1488)	12–19 y (*n* = 1265)
Soft drinks	23.6 ± 3.21	31.8 ± 3.53	36.9 ± 4.47
Diet soft drinks	3.3 ± 1.69[2]	7.3 ± 2.31[3]	6.3 ± 1.63
Tea	29.2 ± 5.08	29.7 ± 5.89	28.6 ± 5.95
Coffee	5.4 ± 2.11[3]	8.8 ± 2.65[3]	18.5 ± 3.08
Flavored milk			
Reduced-fat	5.5 ± 1.24	2.8 ± 0.60	0.4 ± 0.12
Low-fat	3.0 ± 0.90	1.8 ± 0.40	0.2 ± 0.07[3]
Whole	2.4 ± 0.56	2.1 ± 0.46	0.1 ± 0.03[3]
Milk shakes and other dairy drinks	1.0 ± 0.51	1.0 ± 0.32[3]	0.2 ± 0.06[3]
Ice cream and frozen dairy desserts	2.6 ± 0.88[3]	0.8 ± 0.15	0.4 ± 0.10
Cookies and brownies	11.1 ± 2.41	5.6 ± 0.56	1.8 ± 0.31
Cakes and pies	2.1 ± 0.38	1.5 ± 0.40	0.3 ± 0.11[3]
Candy containing chocolate	6.5 ± 1.27	3.9 ± 0.53	1.2 ± 0.22
Sports and energy drinks with caffeine	0.0 ± 0.00	0.0 ± 0.00	4.4 ± 1.57[3]
All others	4.2 ± 0.58	3.1 ± 0.52	0.8 ± 0.17

[1] Values are percentages ± SEs. WWEIA, What We Eat in America. Data Source: NHANES dietary data 2009–2010 (43).
[2] Estimate does not meet standards of reliability or precision; relative SE is ≥40%.
[3] Estimate does not meet standards of reliability or precision; relative SE is >30% but <40%.

for children 2–17 y of age, although no detailed estimates were provided. Branum et al. (29) found no to low caffeine intake from energy drinks in children and adolescents aged 2–18 y but a higher estimate of ~10% in those aged 19–22 y on the basis of NHANES 2009–2010 data. This may be partly related to inclusion of young adults (ages 20–22 y) in their analysis. The findings on caffeine sources from studies relying on NHANES data may be critiqued because they are based on a single 24-h recall. On the other hand, the findings of Mitchell et al. (16) based on the KWP beverage consumption panel involving a 7-d record of beverages consumed also showed that energy drinks contributed little toward caffeine intake for children ≤12 y old. The corresponding estimate in older children (13–17 or 18–24 y) was higher (~10%); caffeine consumption was positively correlated with age (1, 15, 16, 28) and the inclusion of young adults up to age 24 y in the analysis could have overestimated the contribution of CCEDs to caffeine intake in the KWP beverage consumption panel (16). Findings from 2 other national studies that provide information on the frequency of use of energy drinks are important to discuss here. The NPD study of food and beverage consumption in a national sample recorded food diaries over 14 consecutive days in a 2-y survey as described in the report by Somogyi (26); the frequency of energy drink consumption in those aged 2–13 and 14–21 y old was small (<1%). The Monitoring the Future project assessed energy drink/energy shot use along with alcoholic beverages among US middle and high school students (44, 45). The Monitoring the Future study is the only nationally representative study that reported high (30%) use of CCEDs/energy shots among 8th to 12th graders based on a few simple frequency questions that assessed "average" daily consumption among this target age group (44). Future studies targeted at preteens and teens may be needed to precisely determine the proportion and the amounts of caffeine consumed via specific foods such as CCEDs by subpopulation groups on the basis of sociodemographic characteristics. The energy drinks market has expanded and increased in sales since 2011; thus, there is a need to examine the trends in their consumption since 2010, particularly in subgroups such as preteens and teens, as national data from surveys such as NHANES become available.

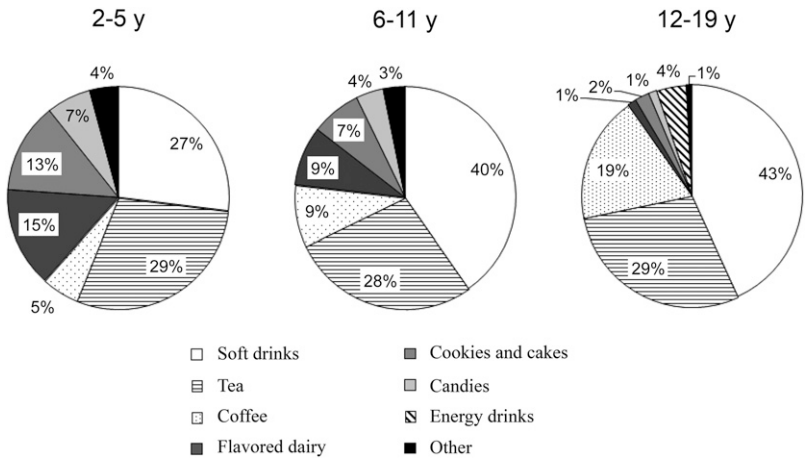

FIGURE 1 Percentage of contribution of the What We Eat in America–based food and beverage categories to caffeine intake by age group: findings from analysis of NHANES 2009–2010 data (43). Values are based on data from *n* = 861, 1154, and 1265 children aged 2–5, 6–11, and 12–19 y, respectively.

TABLE 5 Caffeine from energy drinks in published national studies reviewed and from analysis of NHANES 2009–2010 data using the WWEIA food categories[1]

Source (ref)	Age, y	Percentage consuming energy drinks	Contribution of energy drinks to caffeine intake, %
Mitchell et al. (16)	2–5	Too small to estimate	1.3
	6–12	Too small to estimate	3.7
	13–17	3.7	10.3
	18–24	10.3	9.1
Fulgoni (28)	2–11	NA	NA
	12–17	NA	NA
Branum et al. (29)	2–5	NA	0
	6–11	NA	0
	12–16	NA	3.0
	17–18	NA	2.2
	19–22	NA	10.3
Ahluwalia et al. (30)[2]			
Analyses of NHANES 2009–2010	2–5	0	0
data using WWEIA food categories	6–11	0	0
	12–19	1.7	4.4

[1] NA, not available in the report; ref, reference; WWEIA, What We Eat in America.
[2] Data Source: NHANES dietary data 2009–2010 (43).

Trends in caffeine intake and sources. Studies published in 2014 examined trends in caffeine intake by using NHANES data over varying study periods [e.g., 1999–2010 (29), 2001–2010 (28, 30)] and with varying age groups as described before (Table 1). Fulgoni (28) did not provide details on whether they examined trends over time for all children (aged 2–19 y), whereas Branum et al. (29) found no significant trend in caffeine intake in children and young persons aged 2–22 y. However, the latter report included young adults along with children and teens in the same category; thus, it is difficult to extrapolate their findings to children only. Ahluwalia et al. (30) analyzed data from children and adolescents (aged 2–19 y) and also examined trends over a decade among specific age groups. Caffeine intake declined significantly over the 10-y study period, although the magnitude of change was small (30). In addition, this decline in intake was noted only in younger children (aged 2–5 and 6–11 y) who consumed caffeine, and caffeine intake remained stable over the past decade among teens (aged 12–19 y) who consumed the highest amounts of caffeine among all age groups examined. Consistent with our findings, others also reported a significant linear decrease in mean caffeine intake among consumers (aged 2–11 y) (29). In addition, these authors reported a decreasing trend in caffeine consumption among caffeine consumers for Mexican-American children (but not for other race-ethnic groups).

Few studies examined caffeine intake (16, 30) or trends over time in caffeine consumption expressed in relation to body weight (30). Barone and Roberts (1) reviewed studies up to the early 1990s and found that caffeine intake (mg/kg) declined between 1975 and 1989. Ahluwalia et al. (30) reported a significant, but small, linear decreasing trend from 2001 to 2010 in caffeine consumption in children ages 2–19 y overall. This finding suggests that this declining trend in caffeine intake has likely continued since the late 1980s (**Figure 2**). Importantly, the findings for trends in caffeine consumption were unchanged whether caffeine intake was expressed in absolute amounts (mg) or in relation to body weight (mg/kg) (30).

In view of the increasing choice of products containing caffeine, such as energy drinks targeted to youth, children may be replacing some of their caffeine intake from sodas by other caffeinated products such as coffee or energy drinks, resulting in stable caffeine intake over time, particularly in adolescents. Recent analyses of trends in caffeine intake by food sources by Fulgoni (28) and by Branum et al. (29) confirm this shift in caffeine sources. Both studies reported a decrease in soda consumption by children in all age groups examined. Branum et al. (29) additionally showed a significant increase in caffeine intake from coffee among all age groups examined and from energy drinks only in those aged ≥12 y old.

Taken together, these findings suggest that caffeine intake has generally remained stable or declined slightly in children overall in most studies; in caffeine consumers 2–11 y of age, significant declining trends were noted. The trends in coffee intake are likely related to a shift in patterns of caffeine sources: declining soda consumption and an increase in caffeine from coffee among children of all ages (2–19) and in energy drinks (among adolescents aged 12–19 y). If these trends of increased coffee and energy drink consumption continue, the decline in caffeine intake via decreased soda consumption would not be offset and would likely be associated with an overall increase in caffeine consumption, particularly among older children over time.

Caffeine intakes in relation to guidelines. Caffeine intakes above the 90th percentile have been used to indicate heavy consumption (1, 24). In a few studies, this information was presented for consumers or for all respondents (16, 28, 30). As for average consumption of caffeine, the 90th percentiles were highly age dependent (16, 28, 30). Fulgoni (28) reported that the 90th percentiles of daily usual intake were ~50 mg for children aged 2–11 y and ~100 mg in adolescents aged 12–17 y. Ahluwalia et al. (30) reported that, on a given day, the 90th percentile of caffeine intakes for children and adolescents aged 2–5, 6–11, and 12–19 y were 13, 50, and 148 mg, respectively. As expected, among caffeine consumers, the corresponding numbers were higher (i.e., 21, 58, and 186 mg/d) (30). Our

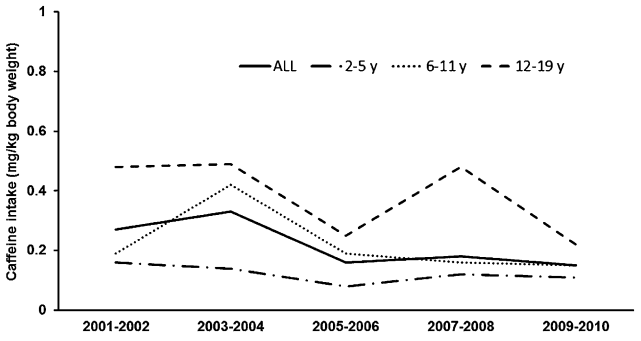

FIGURE 2 Trends over time in caffeine intake in relation to body weight (mg/kg) on a given day in US children aged 2–19 y: findings from NHANES 2001–2010 (30). Trends are shown for all children aged 2–19 y (n = 18,271) and by ages, as follows: 2–5 y (n = 4095), 6–11 y (n = 5288), and 12–19 y (n = 8888). P-linear trend $<$ 0.05 by t statistics for children aged 2–19 y; NS for specific age groups ($P \geq 0.05$).

estimates for younger children are generally similar to those reported previously (23). For older children aged 10–14 and 15–19 y, 90th percentiles for caffeine intake from beverages in the 1999 Share of Intake Panel survey were ~ 75 and ~150 mg/d (23). The differences in age groups examined across studies preclude direct comparisons; however, these data demonstrate that, even among the heavy consumers (intakes above the 90th percentile) caffeine intakes were <200 mg/d.

Few studies reported "heavy consumption" for caffeine intake in relation to body weight (mg/kg). The KWP 7-d beverage consumption survey (16) and the analyses from NHANES 2009–2010 on a given day by Ahluwalia et al. (30) showed that for older children (≥12 y of age) the 90th percentile of caffeine intakes were 2.9 and 2.7 mg/kg, respectively; these estimates were slightly above the 2.5 mg · kg^{-1} · d^{-1} recommendations (38). Ahluwalia et al. showed that, on a given day, 10% of 12- to 19-y-olds and between 10% and 25% of 12- to19-y-old caffeine consumers had caffeine intakes >2.5 mg/kg. Taken together, findings from these recent surveys that describe the upper ends of caffeine intake suggest that some proportion of children, particularly older children (aged 12–19 y), may be consuming more than the suggested daily maximal caffeine intakes (22) and could benefit from increased awareness of potential adverse effects of caffeine.

The American Academy of Pediatrics recommends that children not consume energy drinks (CCEDs). The national studies reviewed here (Table 5) showed that ~2–10% of older children (≥12 y of age) consumed CCEDs on a given day. In addition, among middle and high school students using a simple questionnaire to assess "average" daily CCED/energy shot consumption along with alcohol, higher estimates (30%) were reported (44). Although the proportion of children (aged 12–19 y) reporting CCED use in the most recent quantitative studies is generally small, a consistent and significant trend of an increase in CCED use over time was demonstrated across studies (28, 29). Thus, continued attention needs to be paid to overall caffeine intake and its chief contributors (namely, soda, coffee, and tea) as well as energy drinks that remain "trendy" among adolescents and youth. Surveys specifically targeting these age groups that assess habitual intake over a longer time period with a FFQ in combination with quantitative dietary assessment methods could be useful to continue to monitor caffeine intake in youth in future studies.

Conclusions

Caffeine intake in teenagers has remained fairly stable over time (from the early 2000s to 2010); however, a slight decline was noted in younger children. Sources of intake remain soda, coffee, and tea; in younger children (aged <12 y), flavored milk is an important contributor. Caffeine consumption is higher in older children and in non-Hispanic whites. For children ≥12 y of age, those in the 90th percentile of caffeine intake slightly exceed the recommended maximum guidelines of 2.5 mg · kg^{-1} · d^{-1} by Health Canada. Between 10% and 25% of adolescents aged 12–19 y may be consuming more caffeine than these recommended amounts on a given day. CCED use varied from 2% to 10% across studies that collected detailed quantitative information on foods and/or beverages consumed (e.g., KWP beverage consumption panel and the NHANES). With the statistically significant increasing trend in the use of energy drinks noted in reports based on NHANES data, and the fact that older children (≥12 y of age) had the highest caffeine intake among all children examined, it would be prudent to continue to closely evaluate caffeine intakes and sources, particularly in this age group.

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