Published in final edited form as:

Pediatrics. 2009 June ; 123(6): e975–e981. doi:10.1542/peds.2008-0027.

Estimated Blood Alcohol Concentrations for Child and Adolescent Drinking and Their Implications for Screening Instruments

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Abstract

OBJECTIVES—Although a significant percentage of children drink alcohol, there are as yet few established screening instruments for this population. The construction of such instruments is dependent to some extent on estimates of the effects of different levels of intake of alcohol on children. Blood alcohol concentrations (BAC) in children after consumption of different numbers of standard drinks of alcohol have not previously been estimated.

METHODS—The updated Widmark equation to estimate BAC was modified to take account of the differing body composition (total body water) and accelerated rate of ethanol elimination of children. The modified formula was then used with NHANES 1999-2002 data to estimate BAC for over 4,700 male and female children and adolescents at each age from 9 through 17 years old for intake levels from one through five standard drinks. The goal was to determine the number of drinks at each age that led to a BAC ≥ 80 mg/dL, the National Institute on Alcohol Abuse and Alcoholism criterion for binge drinking.

RESULTS—The estimated BAC for children after consuming just three standard drinks within a 2-hour period was between 80 and 139 mg/dL for boys aged 9-13 and for girls aged 9-17, indicating substantial potential alcohol impairment. At five drinks within 2 hours, the level used to define binge drinking among college students, children aged 9-13 were estimated to have BACs two to three times the adult legal limit for intoxication of 80 mg/dL.

CONCLUSIONS—Binge drinking assessment in children and adolescents requires substantially lower cut-points than those used for college students. Binge drinking should be defined as 3 or more drinks for 9-13 year olds, as 4 or more drinks for boys and 3 or more drinks for girls aged 14 or 15, and as 5 or more drinks for boys and 3 or more drinks for girls aged 16 or 17.

Keywords

Children & Adolescents; Alcohol/Drug Use; Assessment & Surveillance; Epidemiology; Intoxication

The Surgeon General recently issued a Call to Action on Underage Drinking[1] to draw greater public attention to the problem, to encourage more targeted research, and to develop more effective prevention efforts in the underage population. A further implication was to improve

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The author has no financial relationships to disclose relevant to the content of this article.

screening instruments to identify children and adolescents who drink or who engage in hazardous levels of drinking.

There continues to be little consensus, however, regarding how drinking and hazardous drinking should be defined. Drinking has been defined as any alcohol use[2], more than a few sips of alcohol[3], or a full drink of alcohol.[4] Hazardous drinking is often indicated by “binge drinking,” defined as 5+ drinks for men or 4+ drinks for women per occasion.[5] This definition is controversial, however.[6-9]

Recently, the National Institute on Alcohol Abuse and Alcoholism (NIAAA) redefined binge drinking as a drinking pattern that brings a person’s blood alcohol concentration (BAC) to 80 mg/dL or above, a level accompanied by significant physical and mental impairment.[10] For the typical adult, this pattern corresponds to five drinks by a man or four drinks by a woman *within a 2-hour period*.

One problem with the NIAAA definition is that it was developed with adults in mind and has not yet been exemplified in younger populations. Both children and early adolescents weigh substantially less than adults and would likely achieve considerably higher BAC levels after five drinks within a 2-hour period or would reach a BAC ≥ 80 mg/dL after significantly fewer drinks.

In order to estimate the BACs that theoretically would result from consumption of various numbers of drinks in children and adolescents, however, the updated Widmark equation[11, 12] used to estimate BAC in adults needs to be modified so that it relies on more developmentally-appropriate estimates of body composition and ethanol elimination rates. As expressed by Brick[13], the updated Widmark formula for peak BAC is the following:

$$\text{BAC} = (\text{A}/\text{TBW}) \times 80.65 \qquad \text{[Eq.1]}$$

and for BAC after t hours is:

$$\text{BAC} = [(\text{A}/\text{TBW}) \times 80.65] - \beta \text{t} \qquad \text{[Eq.2]}$$

where A = the weight of ethyl alcohol (ethanol) in grams, TBW = Total Body Water or the volume of distribution in liters (estimated from an individual’s height and weight[12]), 80.65 = the percentage of water in blood, β = the ethanol elimination rate per hour, and t = time in hours since the start of drinking.

The aim of the present study is to modify these equations in order to generate BAC estimates that are more developmentally appropriate for children and early adolescents. It will then be possible to determine the appropriate number of drinks to ask about in questions assessing child or adolescent “binge” drinking.

METHODS

This section describes the National Health and Nutrition Examination Survey (NHANES) data, and the procedures used to derive child, adolescent, and adult TBW and ethanol elimination rates. Children younger than age 9 were not included because they are not likely to consume 1-5 full drinks.[14] Adults aged 18 and over were included as a general comparison group.

The NHANES Data Set

Public use data from the 1999-2002 NHANES were used to generate estimates of Total Body Water for children, adolescents, and adults. These data reflect the full range of variation possible in the estimated TBW values and consequently in potential BACs for children at each age. The NHANES is a stratified multistage probability sample of the civilian noninstitutionalized U.S. population. Data from two cycles (1999-2000 and 2001-2002) were merged so that each age-by-gender group would be large enough for the planned analyses. Table 1 presents the distribution of participants by gender and age (ages 9-17 and 18+). Non-Hispanic Blacks, Mexican Americans, and adolescents were over-sampled. Participation rates for the physical examinations were 76.3% in 1999-2000 and 79.6% in 2001-2002.[15]

Body weight was assessed using a Toledo digital scale. Standing height was measured using an electronic fixed stadiometer. Average weight and height were calculated using SUDAAN[16] (see Table 2). Few participants were missing data: 98.3% of children and 96.5% of adults have both variables. Respondents missing either height or weight were omitted from the analyses.

Estimation of Total Body Water (TBW)

The first component of the BAC equation modified for use with children was Total Body Water. In the updated Widmark equation[12, 13], regression equations were developed to estimate TBW for adults using their weight and height. These were used here for the adults. We located similar equations for children aged 8 to 20 that predicted their TBW (assessed by deuterium dilution procedures) using their height and weight.[17] That study determined the best regression weights (multipliers) to use with children's height in cm and weight in kg to estimate their measured scores on TBW (in liters):

$$\text{For boys:}\quad \text{TBW}=-25.87+(0.23\times\text{Height})+(0.37\times\text{Weight}) \qquad [3]$$

$$\text{For girls:}\quad \text{TBW}=-14.77+(0.18\times\text{Height})+(0.25\times\text{Weight}) \qquad [4]$$

Table 2 reports the mean estimates on TBW by gender and age groups as calculated from the NHANES data.

Establishing Ethanol Elimination Rates in Children

Child and adolescent rates of ethanol elimination for the modified BAC equations derive from four published studies,[18-21] identified using MEDLINE, of emergency department (ED) presentations for alcohol intoxication or poisoning by children and adolescents aged 9-17 (the ages of interest here), in which BAC was measured at least twice, permitting determination of hourly ethanol elimination rates. There were a total of 46 cases aged 9-17 (22 males, 24 females) in these studies (37 from one study[21]). Of these, only 4 cases had three BAC assessments, and one case had four assessments before the start of dialysis.[20] In two studies[18, 21], BAC was determined by gas chromatography, while the procedure used was not mentioned in the other two studies which accounted for just 5 of the 46 cases.[19, 20] For consistency across studies, hourly ethanol elimination rates for individuals were calculated by dividing the difference between the first and last BAC by the time elapsed in hours (ΔBAC/ΔHours), and converting from mmol/l/h to mg/dL/h where necessary by dividing by 0.217. Serum ethanol elimination rates (from Simon et al.[21]) were then converted to blood elimination rates by dividing by 1.10.[13]

To examine age differences, all 46 ED cases were assembled into a single dataset. Three cases were excluded: one 15-year-old male[20] with an extreme outlying rate of 53.8 mg/dL/h, and two 16-year-olds[21] (one male, one female) with suspiciously low rates (< 7 mg/dL/h[22]). Table 3 presents the mean and standard deviation for each age group. As may be seen, there is a substantial decrease of over a full standard deviation in the mean elimination rate between ages 12 and 13 (from 20.95 to 15.87 mg/dL/h) but no additional consistent decreases. Fluctuation in the means for ages 13-17 is likely due to the small number at each age. As no extant theory justifies establishing a separate rate for the age-15 group (see footer *a* in Table 3) or categories in adolescence whose elimination rates decrease (at ages 13-14) and then increase (at ages 15-17) before decreasing in adulthood, it was decided to retain just two collapsed age categories (ages 9-12 versus 13-17). Analyses of variance revealed a statistically significant difference in their elimination rates (23.75 ± 6.19 versus 16.79 ± 4.55 mg/dL/h, respectively; F=12.2, df=1, 41, p<.001), accounting for 23% of the variance. Two-way analyses of variance (2×2; observed power=0.85) also found a nonsignificant gender effect (p=.31) and age-by-gender interaction (p=.22). Therefore, two different ethanol elimination rates were used in the BAC equations: one for 9-12 year olds (23.75 mg/dL/h) and one for 13-17 year olds (16.79 mg/dL/h).

Analytic Procedures

The Statistical Package for the Social Sciences (SPSS version 16, Chicago, IL) was used to calculate estimated BACs after 1-5 standard drinks for boys and girls at each age from 9 through 17 and for adults aged 18 and older. A standard drink was defined as 0.6 ounces (oz) of absolute alcohol or 14 grams of ethanol, which translates into 12 oz of beer (5% v/v), 5 oz of wine (12% v/v), or 1.5 oz of 80-proof (40% v/v) distilled spirits.[13, 23] BAC means and 95% confidence intervals (CI) were generated from the NHANES data using estimated TBW values derived from the height and weight data.

Two BAC estimates were calculated: the theoretical maximum BAC (peak BAC) after full absorption of the alcohol consumed [using Eq. 1], and the BAC achieved two hours after this [using Eq 2]. In the latter, the focus was on time since peak BAC because the ethanol elimination rates derived above were measured on the descending limb of the absorption curve (after children's arrival at the ED, usually hours after the start of drinking and presumably after achievement of peak BAC). In Equation 2, time since peak BAC (t) was set at 2 hours for consistency with the NIAAA definition of binge drinking, and the above age-appropriate ethanol elimination rates were used for children and adolescents. For adults, an average ethanol elimination rate of 15 mg/dL/h was used.[24]

The DESCRIPT procedure in SUDAAN 10.0[16] was used to calculate the means and 95% CI on estimated BAC. SUDAAN uses Taylor Series Linearization procedures to estimate variances for complex survey data.

RESULTS

Estimated Peak BAC by Intake

Table 4 presents estimates of the maximum theoretical BAC (peak BAC) for boys and girls at each age from 9 through 17 after 1-5 standard drinks. In general, the greater the number of standard drinks consumed at each age, the higher the estimated BAC. It is also clear that the younger the child, the higher the estimated mean BAC at each level of alcohol intake. For ages 9-13, the estimated peak BACs for boys and girls were comparable at each level of alcohol intake (due to similar mean weights and TBWs). The mean BAC for girls fell within the 95% CI for boys at each of these ages. For ages 14-17, there were sizable sex differences: estimated

BACs were higher for girls than boys at each intake level, with no overlap in their 95% CIs. Children and adolescents had higher estimated BACs than adults at each level of alcohol intake.

At one standard drink, boys and girls could theoretically achieve peak BACs ranging from 62.0 mg/dL for 9-year-old boys to 27.4 mg/dL for 17-year-old boys, and from 61.9 mg/dL for 9-year-old girls to 38.2 mg/dL for 17-year-old girls. At two drinks, the estimated peak BAC for girls aged 9-13 exceeded 80 mg/dL (81.8 to 123.9 mg/dL), while only those for boys aged 9-12 reached this level (84.6 to 124.0 mg/dL). At three drinks, the estimated peak BAC for all children aged 9-17 exceeded the 80 mg/dL NIAAA criterion, and were 2.3 times this level for the youngest children (i.e., 186.0 and 185.8 mg/dL for 9-year-old boys and girls, respectively). At five standard drinks, estimated peak BACs ranged from 137.1 to 309.9 mg/dL for boys and from 191.1 to 309.7 mg/dL for girls, levels that can result in coma and respiratory problems in children and early adolescents.[25]

Estimated BAC Two Hours after Peak

Table 5 presents the BAC estimates for two hours after absorption of 1-5 standard drinks. As above, the more standard drinks consumed at each age, the higher the estimated BAC. Also, the younger the child, the higher the estimated post-peak BAC at each intake level. For ages 9-13, the mean estimated BACs for boys and girls were comparable at each level: mean BACs for girls fell within the 95% CI for boys the same age. For ages 14 through 17, girls had higher estimated BACs than boys at each intake level, with no overlap in their 95% CIs. The same was true for adults. Children and adolescents exhibited higher estimated BACs than adults at each level of alcohol intake.

According to the modified Widmark equation, there would be little or no un-metabolized alcohol for either sex 2 hours after absorption of one drink: estimated mean BACs varied from only 0.2 to 15.4 mg/dL for boys and from 5.1 to 14.5 mg/dL for girls. At three drinks, the estimated post-peak BACs met or exceeded 80 mg/dL for girls aged 9-17. Among the boys, only estimates for those aged 9-13 exceeded 80 mg/dL at 3 drinks. At four standard drinks, the estimated BAC levels exceeded 80 mg/dL for girls at all ages, for adult women, and for boys aged 9-15. At five standard drinks, estimated post-peak BAC levels ranged from 103.6 to 262.4 mg/dL for boys, and from 157.5 to 262.2 mg/dL for girls. For children and early adolescents, BAC levels greater than about 150 mg/dL place them at high risk for coma and respiratory difficulties.[25]

DISCUSSION

Alcohol use by children carries substantial risk for long-term psychiatric and psychosocial consequences. The younger the age at which alcohol use is initiated, the greater the risk for problem drinking in adolescence and for alcohol abuse or dependence in adulthood[26-30], as well as for other problematic outcomes in adolescence, including school absences, delinquent behavior, drinking-driving, smoking, marijuana and other drug use, sexual intercourse, and pregnancy.[28, 31, 32]

In addition, there are acute risks stemming from the higher than heretofore recognized BACs that can result from drinking by children and early to middle adolescents. The present findings suggest that substantially fewer drinks are needed to result in high concentrations of ethanol in children. At present, however, the expected effects of these BACs in children and adolescents are largely theoretical. Only a single experiment in a small sample (22 boys aged 8-15)[33] has examined the effects of alcohol at only a single moderate BAC (35 mg/dL). Although results from this pilot study have been widely interpreted as indicating decreased ethanol sensitivity in children and adolescents, more evidence is clearly needed from larger samples and at higher BACs, perhaps from ED studies (see 25). Animal models suggest reduced adolescent sensitivity to alcohol's sedative effects[34], but generalization to human children demands greater caution.

The present results have implications for the operational definitions of drinking, binge drinking, and heavy drinking. With respect to drinking, results show that at one standard drink, peak BACs were estimated at 30-60 mg/dL, which in adults would result in feelings of relaxation, intoxication, lightheadedness, and euphoria at the lower end, and reduced coordination, increased sociability, lowered inhibitions, lowered alertness and caution, and impaired reasoning, memory and judgment at the higher end.[35] To the extent that children experience the same effects at these BAC levels, it is clearly possible for them to experience ethanol's positive physical and psychological effects after drinking less than a "full drink," even at around half a drink. Consumption of a "full drink" is thus too stringent a criterion to determine which children are drinkers.[4] This decision might better hinge on their having experienced the rewarding effects of alcohol (e.g., relaxation, euphoria, increased sociability), since research has shown that expectations of experiencing such positive effects increase the likelihood of starting to drink and problem drinking in adolescence.[36-38]

The present findings also suggest that substantially lower cut-points be used in children and adolescents to define binge drinking. The estimated mean BACs exceeding 80 mg/dL two hours after peak suggest that cut-points for binge drinking for boys should be set at 3+ drinks for 9-13 year olds, 4+ drinks for 14-15 year olds, and 5+ drinks for 16-17 year olds. For girls aged 9-17, the cut-point for binge drinking should be set at 3+ drinks. Intake of fewer drinks than these at each age should not, however, be considered safe. The higher estimated BACs for girls than boys at ages 14-17 (and lower cut-points) are likely due to the larger muscle mass of boys after puberty, and hence, their greater TBWs (see Table 2).

These results also imply that the operational definition of "heavy drinking" should be modified for children and adolescents. In the National Survey on Drug Use and Health,[39] heavy drinking refers to "binge drinking" on 5+ days in the past month. The use of a more developmentally-appropriate measure of a "binge" would result in higher prevalence rates of heavy drinking among adolescents.

Implications for pediatricians, nurse practitioners, and others involved in child and adolescent health care of the present BAC estimates and recent epidemiologic evidence on children's drinking[14] are that they should screen children as well as adolescents for alcohol use, and that they should intervene at substantially lower levels of alcohol involvement than previously thought. Treating only "5+/4+-drink" binges as evidence of hazardous drinking will miss younger children at substantial risk for impaired intellectual functioning and lowered school achievement resulting from "child-sized" binges that expose their brains to boluses of alcohol shown to affect such outcomes in adolescents.[40]

Given the opportunistic nature of children's drinking, these results likely underestimate actual BACs at each intake level because children, like college students,[41] are likely to pour larger than standard drinks. At the same time, these figures likely overestimate BAC at each intake level for children in countries that use smaller standard drink sizes (e.g., the United Kingdom, Australia, New Zealand).

The larger ethanol elimination rates for children than for adolescents used here are generally consistent with drug metabolism rate differences between children and adults.[42] Children's livers are disproportionately larger for their body size than those of adults until about age 16.[43,44] While the activity levels of alcohol dehydrogenase[45] and the cytochrome P450 isozyme CYP2E1[46-48] in the human liver do not change between ages 9 and 17, the age-related differences in relative liver size imply that there may well be greater overall oxidizing capacity present in children's livers, accounting for their faster ethanol elimination rates.[33]

ED studies of ethanol elimination in larger samples of alcohol-involved children and adolescents are needed to determine age differences in these rates more definitively.

The absence of direct measures of TBW is an important limitation in the present research. Although the predicted TBW values captured the full range of TBW in American children aged 9-17, the tabled means should not be used as national estimates due to the unavailability of anthropometric regression equations for minority children. This unavailability not only introduced some bias, it also prevented racial/ethnic comparisons of the estimated BACs.

Reliance on even an updated and more developmentally-appropriate Widmark equation to estimate blood alcohol levels in children and adolescents does not escape the inherent limitations of this equation. First, it assumes that all of the alcohol is ingested at once, rather than over a span of time. Second, it assumes that the person is in a fasting state, an assumption that is hard to imagine with an adolescent boy. Third, it does not acknowledge the wide variability among individuals in their rates of alcohol absorption and elimination. The present use of the equation, however, does minimize some of the sources of uncertainty in this equation noted by Gullberg[49]: the number of drinks was certain; the alcohol content of a drink was standardized; weight was measured, not estimated; and TBW was estimated from weight and height rather than from Widmark's conversion factors.[11] Despite being based on large numbers of individuals, however, these BAC estimates still have uncertainty built in due to potential errors in the estimation of both TBW and ethanol elimination rates. It is hoped that future research will provide better estimates for both.

The major limitation of the study is, of course, its reliance on an equation for the estimation of children's BAC levels that was not developed through alcohol administration experiments on children and adolescents. These estimates should therefore be considered theoretical and should not be used in pediatric forensic applications. They are at best heuristic approximations developed to advocate against the use of adult operational definitions of hazardous alcohol use in the younger population. Their main virtue is that they are potentially more accurate estimates of child and adolescent BACs than those based on the standard Widmark equation which relies upon adult reference values.

ACKNOWLEDGEMENTS

I would like to thank Drs. Ting-Kai Li and Ralph Hingson for their encouragement to develop this paper expanding on a presentation made on June 11, 2007, at a National Institute on Alcohol Abuse and Alcoholism Underage Drinking Initiative meeting, "Screening for Childhood and Adolescent Drinking and Alcohol Use Disorders among Youth." This research was funded by Grant No. AA-012342 from the National Institute on Alcohol Abuse and Alcoholism.

This research was funded by Grant No. AA-012342 from the National Institute on Alcohol Abuse and Alcoholism.

Abbreviations

BAC, Blood Alcohol Concentration; CI, Confidence Interval; ED, Emergency Department; NHANES, National Health and Nutrition Examination Survey; NIAAA, National Institute on Alcohol Abuse and Alcoholism; TBW, Total Body Water.

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Table 1

Age and Gender Distribution of the 1999-2002 Merged NHANES Sample

Age (Years)	Males n (%)	Females n (%)
9	178 (7.6)	189 (7.9)
10	189 (8.0)	166 (7.0)
11	187 (8.0)	195 (8.2)
12	304 (13.0)	321 (13.5)
13	298 (12.7)	328 (13.8)
14	270 (11.5)	328 (13.8)
15	290 (12.4)	275 (11.6)
16	312 (13.3)	285 (12.0)
17	318 (13.5)	290 (12.2)
9-17	2346 (100.0)	2377 (100.0)
18+	4904	5409
Total	7250	7786

Data were statistically weighted in the analyses to be representative of the U. S. noninstitutionalized population.

Table 2

Means (and Standard Errors) on Weight, Height, and Total Body Water, by Age in Years and Gender (NHANES 1999-2002)

	Weight (kg)		Height (cm)		Total Body Water (L)	
Age in Years	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
9	36.02 (0.67)	35.44 (0.73)	138.06 (0.39)	136.87 (0.69)	19.22 (0.30)	18.77 (0.28)
10	38.58 (0.82)	39.97 (1.03)	141.39 (0.62)	143.25 (0.86)	20.92 (0.39)	21.00 (0.39)
11	43.72 (1.10)	47.93 (1.31)	148.66 (0.90)	151.41 (0.74)	24.49 (0.57)	24.47 (0.43)
12	50.39 (1.26)	51.96 (1.06)	154.76 (0.70)	155.98 (0.68)	28.38 (0.59)	26.30 (0.34)
13	53.90 (1.86)	57.73 (1.37)	160.15 (0.83)	159.09 (0.64)	30.91 (0.86)	28.31 (0.43)
14	63.85 (1.62)	59.86 (1.01)	168.49 (0.91)	161.85 (0.57)	36.50 (0.75)	29.29 (0.29)
15	68.33 (1.14)	61.11 (1.69)	173.83 (0.58)	161.95 (0.64)	39.39 (0.52)	29.64 (0.50)
16	74.43 (1.36)	62.96 (1.16)	175.30 (0.60)	161.92 (0.49)	41.98 (0.57)	30.12 (0.32)
17	75.57 (1.38)	61.81 (1.15)	175.27 (0.57)	163.14 (0.56)	42.40 (0.58)	30.07 (0.34)
18+	86.06 (0.41)	74.11 (0.46)	176.05 (0.13)	162.20 (0.14)	46.16 (0.15)	33.50 (0.12)

Standard errors of the means are in parentheses. Tabled TBWs for children aged 9-17 were calculated from individual height and weight using Equations 3 or 4 in the text. TBWs for adults aged 18+ were calculated using anthropometric equations for men and women in Watson et al.[12, 13]

Table 3

Mean Ethanol Elimination Rates (mg/dL/h) by Age Groups (from Literature Search)

Age (yr)	N	Mean	SD	Range
9-10	4	25.86	7.44	18.4, 36.0
12	3	20.95	3.33	18.4, 24.7
13	4	15.87	4.27	12.6, 22.0
14	6	14.60	4.09	9.6, 20.9
15	6	19.55[a]	6.96	12.6, 29.7
16	8	15.82	4.20	10.9, 21.8
17	12	17.46	3.45	9.6, 21.4
Total	43	17.92	5.43	9.6, 36.0

Age 9 was grouped with Age 10 because there was only a single case. There were no cases aged 11 in the literature. SD = standard deviation, or average distance of scores from the mean. Range = lowest score, highest score.

[a]The mean for Age 15 was influenced by two scores (26.39 and 29.74) well beyond the range of scores for the other teenage groups (ages 13, 14, 16, and 17); excluding these scores, the mean would be 15.29.

Table 4

Means (and 95%CI) on Estimated Theoretical Maximum BAC Level (in mg/dL), by Gender and Age after 1-5 Drinks

	1 Drink	2 Drinks	3 Drinks	4 Drinks	5 Drinks
BOYS/MEN					
9	62.0 (60.2, 63.8)	124.0 (120.4, 127.5)	186.0 (180.6, 191.3)	247.9 (240.9, 255.0)	309.9 (301.1, 318.8)
10	56.6 (54.6, 58.7)	113.3 (109.2, 117.4)	169.9 (163.7, 176.1)	226.6 (218.3, 234.8)	283.2 (272.9, 293.5)
11	48.2 (45.9, 50.6)	96.5 (91.7, 101.2)	144.7 (137.6, 151.9)	192.9 (183.4, 202.5)	241.2 (229.3, 253.1)
12	42.3 (40.4, 44.2)	84.6 (80.8, 88.5)	127.0 (121.2, 132.7)	169.3 (161.6, 176.9)	211.6 (202.0, 221.1)
13	38.8 (36.3, 41.2)	77.6 (72.7, 82.5)	116.4 (109.0, 123.7)	155.2 (145.4, 165.0)	193.9 (181.7, 206.2)
14	32.4 (31.1, 33.7)	64.8 (62.2, 67.5)	97.2 (93.3, 101.2)	129.6 (124.3, 134.9)	162.0 (155.4, 168.6)
15	29.6 (28.7, 30.4)	59.2 (57.5, 60.8)	88.7 (86.2, 91.2)	118.3 (115.0, 121.6)	147.9 (143.7, 152.1)
16	27.7 (27.0, 28.5)	55.5 (53.9, 57.0)	83.2 (80.9, 85.5)	111.0 (107.9, 114.0)	138.7 (134.8, 142.5)
17	27.4 (26.7, 28.2)	54.9 (53.3, 56.4)	82.3 (79.9, 84.6)	109.7 (106.6, 112.9)	137.1 (133.2, 141.1)
18+	25.0 (24.9, 25.1)	50.0 (49.7, 50.3)	75.0 (74.5, 75.4)	100.0 (99.4, 100.5)	124.9 (124.2, 125.7)
GIRLS/WOMEN					
9	61.9 (60.0, 63.9)	123.9 (120.0, 127.8)	185.8 (179.9, 191.7)	247.7 (239.9, 255.5)	309.7 (299.9, 319.4)
10	55.6 (53.4, 57.7)	111.1 (106.8, 115.4)	166.6 (160.3, 173.0)	222.2 (213.7, 230.7)	277.7 (267.1, 288.4)
11	47.6 (46.0, 49.3)	95.3 (92.0, 98.6)	142.9 (138.0, 147.8)	190.6 (184.0, 197.1)	238.2 (230.0, 246.4)
12	44.0 (42.7, 45.2)	88.0 (85.5, 90.5)	132.0 (128.2, 135.7)	175.9 (171.0, 180.9)	219.9 (213.7, 226.1)
13	40.9 (39.7, 42.1)	81.8 (79.3, 84.2)	122.7 (118.9, 126.4)	163.5 (158.6, 168.5)	204.4 (198.2, 210.6)
14	39.2 (38.5, 40.0)	78.5 (77.0, 80.0)	117.7 (115.5, 119.9)	156.9 (154.0, 159.9)	196.2 (192.5, 199.9)
15	38.9 (37.5, 40.4)	77.9 (75.0, 80.8)	116.8 (112.4, 121.1)	155.7 (149.9, 161.5)	194.6 (187.4, 201.9)
16	38.2 (37.4, 38.9)	76.3 (74.7, 77.9)	114.5 (112.1, 116.8)	152.6 (149.5, 155.7)	190.8 (186.8, 194.7)
17	38.2 (37.4, 39.0)	76.4 (74.9, 78.0)	114.7 (112.3, 117.0)	152.9 (149.7, 156.0)	191.1 (187.1, 195.0)
18+	34.4 (34.2, 34.6)	68.8 (68.3, 69.2)	103.2 (102.5, 103.9)	137.6 (136.7, 138.5)	172.0 (170.8, 173.1)

The lower and upper limits for the 95% Confidence Interval about the mean are presented in parentheses. To estimate mean BAC for 1-5 standard drinks at any time interval of interest since peak BAC, simply multiply the appropriate age-specific ethanol elimination rate by the number of hours of interest and subtract this from the mean peak BACs in this table.

Table 5

Means (and 95%CI) on Estimated BAC Level 2 Hours after Peak BAC (in mg/dL), by Gender and Age after 1-5 Drinks

	1 Drink	2 Drinks	3 Drinks	4 Drinks	5 Drinks
BOYS/MEN					
9	15.4 (13.8, 17.0)	76.5 (72.9, 80.0)	138.5 (133.1, 143.8)	200.4 (193.4, 207.5)	262.4 (253.6, 271.3)
10	10.6 (8.7, 12.4)	65.8 (61.7, 69.9)	122.4 (116.2, 128.6)	179.1 (170.8, 187.3)	235.7 (225.4, 246.0)
11	4.6 (3.0, 6.3)	49.0 (44.2, 53.7)	97.2 (90.1, 104.4)	145.4 (135.9, 155.0)	193.7 (181.8, 205.6)
12	2.2 (1.3, 3.1)	37.2 (33.4, 41.0)	79.5 (73.7, 85.2)	121.8 (114.1, 129.4)	164.1 (154.5, 173.6)
13	6.7 (4.6, 8.7)	44.0 (39.1, 48.9)	82.8 (75.4, 90.1)	121.6 (111.8, 131.4)	160.4 (148.1, 172.6)
14	2.3 (1.5, 3.0)	31.2 (28.6, 33.9)	63.6 (59.7, 67.6)	96.0 (90.8, 101.3)	128.4 (121.8, 135.0)
15	0.8 (0.5, 1.1)	25.6 (23.9, 27.2)	55.2 (52.7, 57.7)	84.7 (81.4, 88.1)	114.3 (110.1, 118.5)
16	0.3 (0.1, 0.5)	21.9 (20.4, 23.4)	49.6 (47.3, 51.9)	77.4 (74.3, 80.5)	105.1 (101.3, 109.0)
17	0.2 (0.1, 0.4)	21.3 (19.8, 22.9)	48.7 (46.4, 51.1)	76.1 (73.0, 79.3)	103.6 (99.7, 107.5)
18+	0.15 (0.1, 0.2)	20.0 (19.7, 20.3)	45.0 (44.5, 45.4)	70.0 (69.4, 70.5)	94.9 (94.2, 95.7)
GIRLS/WOMEN					
9	14.5 (12.6, 16.5)	76.4 (72.5, 80.3)	138.3 (132.4, 144.2)	200.2 (192.4, 208.0)	262.2 (252.4, 271.9)
10	9.0 (7.2, 10.9)	63.6 (59.3, 67.9)	119.1 (112.8, 125.5)	174.7 (166.2, 183.2)	230.2 (219.6, 240.9)
11	3.4 (2.4, 4.4)	47.8 (44.5, 51.1)	95.4 (90.5, 100.3)	143.1 (136.5, 149.6)	190.7 (182.5, 198.9)
12	1.5 (0.9, 2.0)	40.5 (38.0, 43.0)	84.5 (80.7, 88.2)	128.4 (123.5, 133.4)	172.4 (166.2, 178.6)
13	7.7 (6.6, 8.8)	48.2 (45.7, 50.7)	89.1 (85.4, 92.8)	130.0 (125.0, 134.9)	170.8 (164.7, 177.0)
14	6.1 (5.5, 6.7)	44.9 (43.4, 46.4)	84.1 (81.9, 86.4)	123.4 (120.4, 126.3)	162.6 (158.9, 166.3)
15	5.8 (4.5, 7.1)	44.3 (41.4, 47.2)	83.2 (78.9, 87.6)	122.1 (116.3, 127.9)	161.1 (153.8, 168.3)
16	5.1 (4.5, 5.8)	42.7 (41.2, 44.3)	80.9 (78.5, 83.2)	119.0 (115.9, 122.2)	157.2 (153.3, 161.1)
17	5.1 (4.5, 5.7)	42.9 (41.3, 44.4)	81.1 (78.7, 83.4)	119.3 (116.1, 122.4)	157.5 (153.6, 161.4)
18+	4.9 (4.7, 5.1)	38.8 (38.3, 39.2)	73.2 (72.5, 73.9)	107.6 (106.7, 108.5)	142.0 (140.8, 143.1)

The lower and upper limits for the 95% Confidence Interval about the mean are presented in parentheses. The legal *per se* definition of Driving Under the Influence (DUI) is BAC $\geq$ 80 mg/dL.