

# Adolescent Binge Drinking

## *Developmental Context and Opportunities for Prevention*

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*Binge drinking, commonly defined as consuming five or more standard drinks per occasion for men and four or more drinks for women, typically begins in adolescence. Adolescents, although they may drink less often, tend to consume higher quantities of alcohol per occasion compared with adults. This developmental difference in pattern of alcohol consumption may result, in part, from maturational changes that involve an adolescent-specific sensitivity to certain alcohol effects and greater propensity for risk-taking behaviors, such as binge drinking. Adolescent binge drinking is associated with a range of acute alcohol-related harms, some of which may persist into adulthood. The prevalence of binge drinking, including high-intensity drinking (i.e., 10 or more and 15 or more drinks per occasion), has declined among adolescents in recent years. Overall, however, the proportion of youth who engage in binge drinking remains high. This article reviews the definition and prevalence of binge drinking in adolescence, trajectories of binge drinking and their correlates, and implications for prevention.*

**Key words:** Alcohol consumption; binge drinking; brain development; college students; high-intensity drinking; underage drinking

Compared with adults, adolescent drinkers tend to consume higher quantities of alcohol per occasion but drink less frequently.<sup>1</sup> Thus, underage drinkers ages 12 to 20 typically consume 4 to 5 drinks per drinking episode, which is nearly double the average of the 2 to 3 drinks usually consumed by adults (older than age 25).<sup>1</sup> Most of the alcohol consumption of underage drinkers occurs during “binge” episodes characterized by drinking high quantities.<sup>2,3</sup> This binge pattern of consumption has been linked to serious alcohol-related harm, such as alcohol poisoning, as well as to sometimes fatal injuries and accidents resulting from acute intoxication.<sup>4</sup> The adverse consequences of adolescent binge drinking affect not only the adolescents but also their families, peers, and community.<sup>5</sup>

This article reviews various definitions of binge drinking, the acute adverse consequences associated with binge drinking, the prevalence of adolescent binge drinking, and demographic factors (e.g., gender and race/ethnicity) associated with adolescent binge drinking. It then discusses the developmental context of adolescent binge drinking, including adolescent-specific sensitivity to certain alcohol effects that may contribute to episodes of high-volume alcohol consumption in adolescence. After a summary of trajectories of binge drinking in adolescence, trajectory correlates representing risk factors and young-adult outcomes, and possible neurocognitive consequences of adolescent binge drinking, the implications of research on adolescent binge drinking for prevention efforts are briefly reviewed.

### Definitions of Binge Drinking for Youth

Binge drinking, or an episode of high-volume alcohol consumption, has been defined in various ways.<sup>6,7</sup> (For more information, see **Drinking Patterns and Their Definitions** in this issue.) According to the National Institute on Alcohol Abuse and Alcoholism (NIAAA),<sup>8</sup> “binge drinking” refers to alcohol consumption that brings the blood alcohol concentration (BAC) to .08 g/dL, which is commonly associated with acute impairment in motor coordination and cognitive functioning.<sup>9</sup> BACs of more than .08 g/dL typically occur in men after consuming five or more drinks in about 2 hours, and in women after consuming four or more drinks. This is known as the “5+/4+” binge definition. This definition is consistent with

epidemiological data indicating an association at the population level between greater frequency of 5+/4+ binge episodes and more adverse drinking-related consequences.<sup>10</sup>

When applied to adolescents, binge-drinking definitions based on adult levels of alcohol intake (e.g., 5+/4+ drinks per occasion) often are too high. Children and adolescents are likely to reach BACs of more than .08 g/dL at lower levels of consumption due, in part, to factors such as smaller body size. Donovan used an updated Widmark equation and population data on average body weight in boys and girls to estimate the levels of drinking that would produce BACs of more than .08 g/dL in youth ages 9 to 17.<sup>11</sup> For those ages 9 to 13, a binge episode was estimated to occur with intake of 3 or more drinks within a 2-hour period; for those ages 14 to 15, with 4 or more drinks for boys and 3 or more drinks for girls; and for those ages 16 to 17, with 5 or more drinks for boys and 3 or more drinks for girls. These proposed binge-drinking thresholds for youth are theoretical and based on estimated, rather than observed, BACs. Nevertheless, the identification of lower drinking-quantity thresholds to define binge drinking for younger drinkers suggests that the use of standard adult-based binge definitions may underestimate the prevalence of drinking behavior that leads to BACs of more than .08 g/dL, particularly among females and youth.

Extreme binge, or high-intensity, drinking involves the intake of dangerously high quantities of alcohol per occasion. (For more information, see **High-Intensity Drinking** in this issue.) Thresholds of 10 or more drinks (i.e., double the usual definition of binge drinking of 5 or more drinks) and 15 or more drinks per occasion (i.e., triple the usual definition of binge drinking of 5 or more drinks), as well as gender-specific cutoffs of 8 or more drinks for females and 10 or

more drinks for males, respectively, have been used to define high-intensity drinking.<sup>12-14</sup> These definitions specify thresholds that are two to three times higher than the 5+/4+ binge definition and have been examined in part because of limitations in the reliability of the 5+/4+ binge definition for identifying drinkers with BACs of more than .08 g/dL.<sup>15</sup> As a point of reference, among adolescent drinkers, alcohol-related blackouts, or acute alcohol-related memory loss, may occur after consuming nine or more drinks per occasion for males and five or more drinks for females.<sup>16</sup>

### Acute Adverse Consequences of Binge Drinking

Acute negative alcohol-related consequences generally show a dose-response relationship with binge drinking,<sup>17</sup> such that greater risk for many adverse consequences has been associated with higher drinking quantities and more frequent binge episodes.<sup>18-20</sup> A significant literature has examined the diverse acute health harms associated with binge drinking, such as alcohol poisoning, alcohol-related blackouts and injury, involvement in car crashes and fatalities, alcohol-related physical and sexual assault, increased risk for sexually transmitted infection, and problems at school or work.<sup>4,21</sup> Risk behaviors associated with binge drinking may include, for example, simultaneous use of other substances (e.g., marijuana) and greater likelihood of riding with an intoxicated driver.<sup>22</sup> Although many of the acute adverse consequences of binge drinking are not unique to adolescents, young drinkers may be at higher risk than adult drinkers for certain acute alcohol-related harms (e.g., alcohol poisoning) because of their relative inexperience with alcohol's effects. Importantly, although some adolescent heavy drinkers meet the criteria for an alcohol use disorder

(2.7% of those ages 12 to 17), many more youth report binge alcohol use (6.1%)<sup>23</sup> and may experience acute adverse effects from binge drinking that are not covered by diagnostic criteria.

### Prevalence of Adolescent Binge Drinking

Numerous studies have assessed the prevalence of adolescent binge drinking in the United States, as well as in other countries. These studies also have assessed the association between binge-drinking rates and demographic characteristics.

#### *Trends in the Prevalence of Adolescent Binge Drinking in the United States*

Three national surveys in the United States provide data on the prevalence of adolescent binge drinking, including the National Survey on Drug Use and Health (NSDUH), which until 2015 defined binge drinking as consumption of five or more drinks on the same occasion;\* the Monitoring the Future (MTF) survey, which defines it as five or more drinks in a row; and the Youth Risk Behavior Survey (YRBS), which defines it as five or more drinks of alcohol in a row—that is, within a couple of hours. (For more information on these surveys, see **Surveys That Include Information Relevant to Binge Drinking** in this issue.) Thus, until 2015, these surveys all used the same threshold to define binge drinking in males and females, albeit with slightly different wording and with differences in the time frame used to assess binge drinking (i.e., within the past month for the NSDUH and YRBS, and within the past 2 weeks for the MTF). The NSDUH has collected annual data since 1991 on individuals ages 12 and older using interviews conducted in the home.<sup>5</sup> In contrast, both MTF and YRBS are school-based

\*Since 2015, the NSDUH defines binge drinking as consumption of 4 or more drinks for women or 5 or more drinks for men on the same occasion on at least 1 day in the past 30 days.

surveys. MTF has collected annual data since 1975 from 12th graders, and since 1991 from 8th, 10th, and 12th graders.<sup>24</sup> YRBS has collected data biennially since 1991 from 9th to 12th graders.<sup>25</sup>

All three surveys show similar time trends in adolescent binge drinking.<sup>26</sup> The MTF data indicate a peak in the prevalence of youth binge drinking in the late 1970s to early 1980s, followed by a decrease from 41% in 1983 to 28% in 1992.<sup>24</sup> In the 2015 MTF survey, binge drinking in the past 2 weeks was reported by 4.6% of 8th graders, 10.9% of 10th graders, and 17.2% of 12th graders.<sup>24</sup> This reduction in youth binge-drinking prevalence over time may reflect factors such as enactment of a minimum legal drinking age of 21 and other alcohol regulatory policies.<sup>4,27</sup> Time-trend data from the YRBS (from 1999 to 2013) and NSDUH (from 2002 to 2014) indicate a similar decrease in youth binge drinking in recent years.<sup>5,25</sup>

The prevalence of high-intensity drinking (10 or more or 15 or more drinks in a row in the past 2 weeks) was relatively stable among high school seniors in the MTF from 2006 to 2012, but, like binge drinking, has shown a decline in recent years. Thus, the prevalence of consuming 10 or more drinks in a row declined from 10.4% in 2012 to 6.1% in 2015, and the prevalence of consuming 15 or more drinks in a row declined from 5.5% in 2012 to 3.5% in 2015.<sup>24</sup>

In all three national surveys, binge-drinking prevalence increases with age during adolescence. For example, in 2015, the most recent year in which all three national surveys collected data on binge drinking, NSDUH indicated that 9.6% of youth ages 12 to 17 reported alcohol use in the past month, with roughly half (i.e., 5.8%) of these drinkers reporting binge drinking in the past month.<sup>28</sup> Among respondents ages 12 to 17 in the 2015 NSDUH, past-month binge-drinking prevalence increased from 0.5% at ages 12 to 13 to 15.3% at age 17. In the 2015 YRBS, 17.7%

of all high school students reported binge drinking in the past month, increasing from 10.4% in 9th graders to 24.6% in 12th graders.<sup>29</sup> According to the 2015 MTF survey, 4.6% of 8th graders, 10.9% of 10th graders, and 17.2% of 12th graders reported binge drinking in the 2 weeks prior to the survey.<sup>24</sup>

The results from these three national surveys are broadly consistent in a given year, although YRBS data generally indicate somewhat higher binge prevalences compared with NSDUH and MTF, and MTF tends to report higher prevalences compared with NSDUH.<sup>26</sup> The differences in binge-drinking prevalence across the surveys may result from methodological differences, such as sampling strategy used, survey location (e.g., school or home), type of data collection (e.g., paper survey or self-administered computer assessment), item wording, and time frames for querying binge drinking.<sup>26</sup> Interpretation of results from these national surveys also needs to consider that use of the “5+” binge definition in these surveys may underestimate the prevalence of binge drinking in younger adolescents and females, because, as mentioned earlier, lower drinking-quantity thresholds to define binge drinking are indicated in this age group.<sup>11</sup>

### ***International Surveys of Adolescent Binge-Drinking Prevalence***

International data on the prevalence of adolescent binge drinking are available from sources such as the European School Survey Project on Alcohol and Other Drugs (ESPAD) and the Australian School Students Alcohol and Drug (ASSAD) survey. In 2011, the ESPAD report on 15- to 16-year-old students in 36 European countries indicated that the average prevalence of consuming 5 or more drinks on at least 1 occasion in the past 30 days was 39% across countries.<sup>30</sup> However, ESPAD countries differed in the average alcohol quantity that students reported consuming on their most recent

drinking day. Thus, students in Nordic countries and the British Isles generally reported consuming a higher average quantity than did students in southeastern Europe (e.g., Greece or Italy).<sup>30</sup> By comparison, the 2011 ASSAD survey found that among students ages 12 to 17 who reported drinking in the week prior to the survey (17.5% of all students queried), more than one-third (36.2%) drank 5 or more drinks in a day.<sup>31</sup>

In general, countries with lower legal drinking ages have a higher prevalence of adolescent binge drinking compared with countries with higher legal drinking ages.<sup>32</sup> Also, rates of adolescent binge drinking generally are higher in many European countries<sup>4</sup> and Australia<sup>31</sup> than in the United States. However, such variations in binge-drinking prevalence across studies need to be interpreted with caution because methodological differences (e.g., in sampling method, ages covered, item wording, time frames, and the definition of a standard drink) exist across surveys.

### ***Adolescent Binge-Drinking Prevalence by Demographic Characteristics***

In general, males tend to report higher rates of binge drinking in adolescence than do females (see Figure 1).<sup>13,14,23,24</sup> These gender differences typically increase with age during adolescence.<sup>22,30,33</sup> However, time-trend data from MTF have indicated a narrowing of the gender gap starting in the mid-1970s, particularly among high school seniors. Thus, in the 1975 MTF, 49% of male high school seniors, but only 26% of females, reported binge drinking, corresponding to a 23-percentage-point difference. By 2014, in contrast, a mere 5-percentage-point difference existed between male (22%) and female (17%) high school seniors who reported binge drinking.<sup>33</sup> Conversely, NSDUH time-trend data from 2002 to 2012 for youth ages 12 to 17 indicate that although binge drinking

decreased for both males (from 11.3% in 2002 to 7.4% in 2012) and females (from 10.2% in 2002 to 6.8% in 2012), with more males than females reporting binge drinking at both time points, there was little support for a narrowing of the gender gap over these years.<sup>34</sup> The time-trend results for gender differences from the MTF and NSDUH surveys are not directly comparable because of differences in the ages covered, as well as in item wording and time frames assessed (i.e., the MTF asked about 5 or more drinks in a row in the past 2 weeks, whereas the NSDUH asked about 5 or more drinks on an occasion in the past month). Nevertheless, both surveys indicate greater binge-drinking prevalence among male than among female adolescents.<sup>22</sup>

The prevalence of adolescent binge drinking in the United States also differs by race/ethnicity (see Figure 1). Among adolescents ages 12 to 17 in the 2014 NSDUH, the prevalence of past-month binge drinking was higher among Whites (7.1%) and Hispanics/

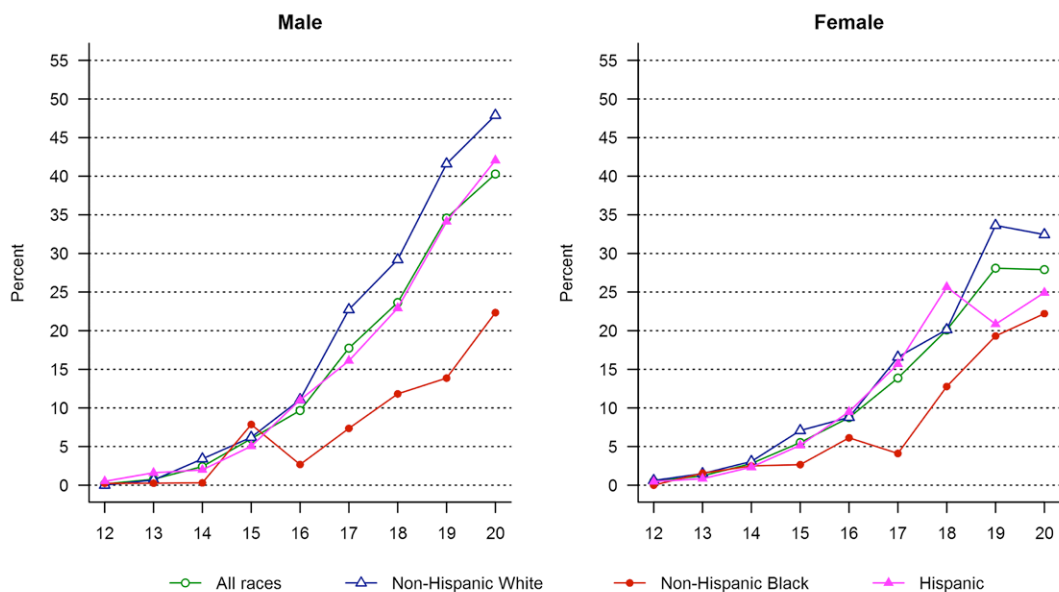
Latinos (6.3%) compared with Blacks (3.6%) and Asians (1.5%).<sup>23</sup> MTF time-trend data from 1975 to 2014 suggest that these race/ethnic differences may differ by year in high school.<sup>33</sup> For example, among 8th-grade students, more Hispanics tended to report binge drinking compared with Whites and Blacks. Among 10th- and 12th-grade students, however, Hispanics and Whites were more likely to report binge drinking than were Blacks.

In the United States, binge-drinking prevalence also varies by region, with differences observed between and within states (see Figure 2).<sup>33</sup> For example, based on recent NSDUH data, past-month binge-drinking prevalence among underage drinkers ages 12 to 20 at the state level was highest in four states in the Northeast, four states in the Midwest, the District of Columbia, and one state in the West.<sup>35</sup> Even within a region, such as the District of Columbia, subregions differed in the prevalence of past-month binge drinking, ranging from 10.8% to 42.4%

in the District of Columbia, with an overall estimate of 18.0%.<sup>35</sup> High-intensity or extreme binge-drinking prevalence was especially high among high school seniors in the Midwest.<sup>13</sup> Binge-drinking prevalence also differed by urban versus rural setting, with high school students living in rural areas tending to report the highest rates of binge drinking.<sup>33</sup> These regional differences suggest that factors such as local and regional norms regarding alcohol use, as well as local alcohol regulatory policies and enforcement, have an important influence on prevalence of binge drinking.

## Developmental Context of Adolescent Binge Drinking

During adolescence, ongoing brain development and rapid changes in physical maturation occur in the context of a shift from parents and family to peers as a primary source of support and guidance.<sup>36,37</sup> These normative, adolescent-specific changes in

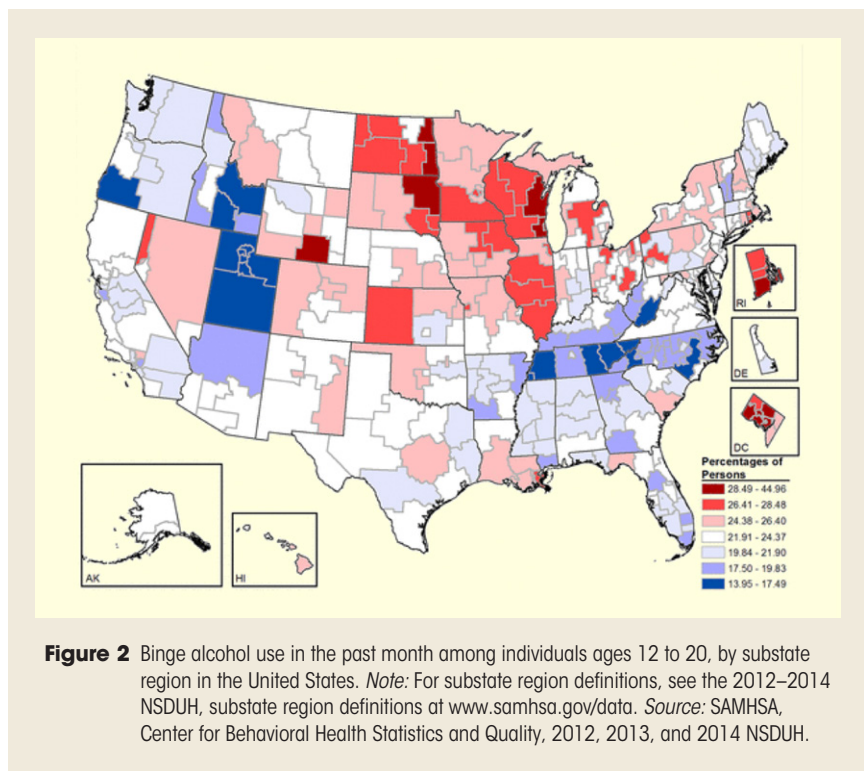


**Figure 1** Prevalence of binge drinking in the past 30 days among 12- to 20-year-olds, by age, sex, and race/Hispanic origin, as reported in the 2013 NSDUH.



physical maturation and social context can contribute to the risk for binge drinking. In particular, the fine tuning of the neural circuitry that occurs during this developmental period is associated with an adolescent-specific elevation in the ability to consume alcohol, which appears to be conserved across species.<sup>38</sup> Animal (e.g., rodent) models indicate that neural changes occurring in adolescence may temporarily increase sensitivity to certain alcohol effects (e.g., rewarding effects) that promote consumption within a drinking episode, while reducing sensitivity to other effects (e.g., sedative effects) that may help to limit drinking during an episode.<sup>38</sup> Evidence for such an adolescent-specific sensitivity to alcohol effects in humans is sparse but aligns with animal models to suggest that compared with their adult counterparts, human adolescents may be more sensitive to alcohol's rewarding and stimulant effects<sup>39</sup> and less sensitive to its sedative effects.<sup>40</sup> Related research has found that, among college students, high-intensity binge drinking (i.e., 8 or more/10 or more drinks for females/males) is experienced as more rewarding than non-high-intensity drinking (i.e., less than 8/10 drinks for females/males).<sup>41</sup> Furthermore, many college students reported willingness to tolerate adverse alcohol effects in order to experience the positive effects associated with high-intensity drinking.<sup>41</sup>

The adolescent-specific shift from family to peers as important sources of influence on youth attitudes and behavior also can contribute to risk-taking behaviors, such as binge drinking.<sup>42,43</sup> Higher levels of sensation seeking and impulsivity, which are associated with risk-taking behaviors and binge drinking, tend to be endorsed more often by adolescent males than by females, which may help explain the generally greater prevalence of binge drinking among males.<sup>44</sup> Risk-taking behavior may be facilitated by the presence of peers.<sup>43</sup> Consistent with this observation, adolescent binge drinking tends to occur in social contexts with peers.<sup>45,46</sup> This may encourage episodes



of high-volume consumption through mechanisms such as peers providing access to alcohol, peer norms that are favorable to binge-drinking behavior, and positive feelings generated by social activities that involve alcohol use.<sup>37,47</sup>

Binge drinking among underage drinkers in the United States often involves distilled spirits, with consumption of beer reported in less than one-third of binge episodes.<sup>48</sup> For some youth, consumption of liquor may reflect the intent to drink to get drunk as quickly as possible. The preferential consumption of liquor by adolescents during binge episodes is particularly concerning because it has been linked with increased risk for alcohol-related consequences, such as blackouts or injury.<sup>49</sup>

Young drinkers also often lack knowledge regarding standard drink servings, particularly for spirits, which can result in overpouring—that is, pouring greater volumes than used for standard drink servings.<sup>50</sup> Overpouring

can increase the likelihood of high-volume consumption, rapid intoxication, and risk for certain alcohol-related harms, such as blackouts.<sup>50</sup>

Other contextual factors relevant to adolescent binge drinking include the places where drinking occurs and the temporal patterning (e.g., weekend or seasonal) of drinking. For example, certain places where adolescent binge drinking occurs, such as at someone else's home without parental supervision or at a bar or nightclub, have been associated with greater risk for alcohol-related violence.<sup>51</sup> With regard to temporal patterning, the timing of adolescent binge drinking shows some predictability: Binge drinking may be more likely to occur during weekends, summer and spring breaks, holidays (e.g., New Year's Eve), and occasions such as prom and sports events.<sup>52</sup> These contextual factors, in combination with an adolescent-specific sensitivity pattern to alcohol effects and the peer social context of drinking, may interact with individual difference

factors, such as heritable risk and exposure to trauma, in contributing to increased risk for binge drinking and related harm in adolescence.<sup>38</sup>

## Binge-Drinking Trajectories in Adolescence

The onset of alcohol use peaks during grades 7 to 11.<sup>24</sup> By 8th grade, 11% of students report having been drunk (a self-report proxy for high-quantity consumption) at least once in their lifetime, with an increase to 29% among 10th graders and 47% among high school seniors.<sup>24</sup> Reports of the onset of consuming 3 or more drinks per occasion begin to increase between ages 13.5 and 15.5, and reports of an episode of binge drinking (5 or more drinks per occasion) start to rise around age 16.<sup>53</sup> Although rates of binge drinking peak between ages 18 and 25,<sup>54</sup> the onset of binge drinking (i.e., 3 or more or 5 or more drinks per occasion) and episodes of being drunk typically occur in early to mid-adolescence (i.e., ages 12 to 16). Early age of first intoxication (younger than 15 years old) and rapid progression from first drink to first intoxication both are early warning signs of heavy, particularly binge, drinking.<sup>55,56</sup>

Longitudinal studies that span adolescence through emerging adulthood (i.e., ages 12 to 25) have identified three to five prototypical trajectories of binge drinking (see Figure 3).<sup>57-63</sup> The trajectories derived in these studies provide useful heuristics for understanding different patterns of change in binge drinking across adolescence. They highlight heterogeneity in course, and differ with respect to age at onset of binge drinking; timing, rate, and direction of change in binge drinking (e.g., escalation and desistance); and frequency of binge drinking.

Most youth in community samples fall into the low-frequency binge-drinking and nonbinge-drinking

trajectories. In some studies, nonbinge trajectories may include youth who drink but do not report binge episodes, as well as abstainers.<sup>59,60</sup> Trajectories indicating persistence of binge drinking from adolescence into young adulthood, which typically represent a minority of youth in community samples, tend to show onset of binge drinking in early adolescence (i.e., at ages 12 to 13) and an increase to weekly or more frequent binges by late adolescence (i.e., at ages 17 to 18).<sup>7</sup> Other binge-drinking trajectories are characterized by earlier (e.g., age 16 and younger) versus later (e.g., age 17 and older) onset of binge drinking or by a pattern of adolescent-limited binge drinking, in which binge drinking peaks in adolescence, then declines in early adulthood.<sup>7</sup> One study that followed a high-risk sample of youth into young adulthood identified four types of binge-drinking<sup>†</sup> trajectories, including nonbinger (39.5%), infrequent (9.6%), late-onset moderate (30.0%), and early-onset heavy drinking (20.9%).<sup>57</sup> Studies vary in the relative proportions of youth in each trajectory type because of methodological factors, such as differences in sampling (e.g., community vs. high-risk sample), age range, binge-drinking definition, and whether nonbinge trajectories include both abstainers and drinkers who do not report binge episodes.

## Correlates of Adolescent Binge-Drinking Trajectories: Risk Factors and Young-Adult Outcomes

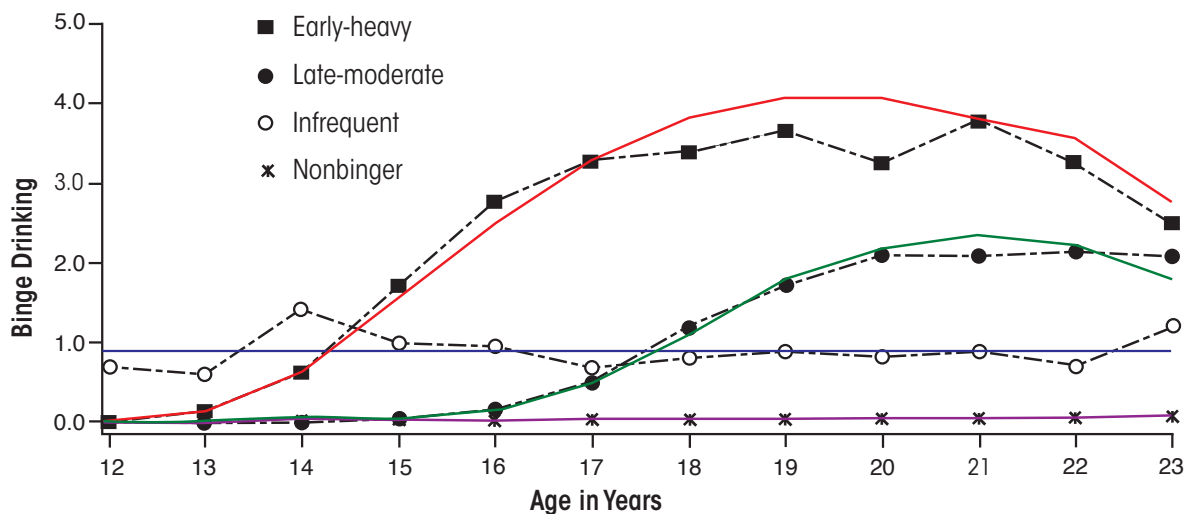
Distinct trajectories of binge drinking are thought to reflect different etiologic mechanisms.<sup>64</sup> According to an ecological systems model,<sup>36,65</sup> these etiologic mechanisms represent multiple systems (e.g., family, peer group, and community) that interact across development to influence binge-drinking trajectories.

Developmental factors associated with an increase in binge drinking during adolescence include, for example, reduced parental monitoring as youth mature<sup>37,66</sup> and greater independence (e.g., obtaining a driver's license) in daily activities.<sup>36</sup> In addition, for some youth, onset of binge drinking may be associated with important school transitions (e.g., junior high to high school or high school to college), which can involve restructuring of peer groups and increased opportunities to engage in alcohol use.<sup>36</sup> Importantly, processes of peer selection and peer influence have been associated with changes in binge drinking in adolescence.<sup>67-69</sup> In particular, selection of peers who engage in binge drinking has been associated with an adolescent's initiation and frequency of binge drinking.<sup>69</sup>

Several studies analyzed factors associated with binge trajectories, relative to nonbinge trajectories, at the individual level. Nonbinge trajectories in these studies included youth who abstained and youth who reported alcohol use below a given binge threshold. Risk factors identified in these studies included, for example, engaging in delinquent behavior, exposure to more stressful life events, and lower task persistence.<sup>61-63</sup> Some of these risk factors may be associated with gender; for example, females may be more likely to experience certain stressful life events (e.g., sexual trauma), whereas males may be more likely to be involved in delinquent behavior or to show lower levels of impulse control.<sup>44,70</sup> Moreover, in contrast to youth in binge-drinking trajectories, youth in nonbinge trajectories were more likely to report greater self-efficacy to resist social pressure to engage in substance use,<sup>62</sup> as well as greater religiosity.<sup>63</sup>

With regard to the social context in which youth are nested, parental alcoholism and disrupted family relations (e.g., parental separation or divorce) each were associated with binge-drink-

<sup>†</sup>The study defined binge drinking as "5+ drinks in a row."



**Figure 3** Trajectories of binge drinking from adolescence through emerging adulthood. Estimated growth trajectories for the three groups are indicated by solid lines. Dashed black lines represent observed means of binge drinking at each age for each group. Observed frequencies of binge drinking (past year) ranged from 0 (none) to 5 (one to two times a week). *Note:* Early-heavy group,  $n = 99$ , 20.9% of the sample. Late-moderate group,  $n = 134$ , 30.0% of the sample. Infrequent group,  $n = 43$ , 9.6% of the sample. Nonbinger group,  $n = 176$ , 39.5% of the sample. *Source:* Chassin L, Pitts SC, Prost J. Binge drinking trajectories from adolescence to emerging adulthood in a high-risk sample: Predictors and substance abuse outcomes. *J Consult Clin Psychol.* 2002;70(1):67-78. Copyright © 2002 by the American Psychological Association. Reprinted with permission.

ing trajectories.<sup>57,62</sup> Conversely, an adolescent's perception of high parental disapproval of substance use was prospectively associated with a nonbinge trajectory.<sup>60</sup> Peer relations also had an impact, because changes in binge drinking tended to occur in parallel with changes in affiliation with drinking peers.<sup>60</sup> However, despite the robust influence of peers on drinking behavior, an adolescent's report of high parental disapproval of substance use weakened the effect of peers on binge drinking,<sup>60,69</sup> indicating the important role that parents play in providing clear messages to their children regarding disapproval of underage drinking. It is important to note, however, that many individual and social risk factors associated with adolescent alcohol and other substance use have a more general influence and are not necessarily specific to binge drinking.

Community-level influences on adolescent binge-drinking trajectories

include factors such as neighborhood and school environments, as well as local alcohol regulatory policies and enforcement. For example, one study found that youth living in neighborhoods with higher densities of on-premise alcohol outlets (e.g., bars and nightclubs) were more likely to report binge drinking, controlling for neighborhood-level socioeconomic status.<sup>71</sup> However, neighborhood risks may be buffered by protective factors. In particular, a recent study found that a supportive school environment (e.g., alcohol prevention incorporated into the curriculum) was associated with reduced adolescent binge drinking over and above individual, family, and peer risk factors.<sup>72</sup> Further, comprehensive and stringent local alcohol control policies and enforcement have been associated with lower levels of youth binge drinking, highlighting the importance of these community-level factors.<sup>73</sup> The unique and cumulative effects of fam-

ily, peer, and community influences on youth binge drinking emphasize the need for coordinated, developmentally tailored prevention programs that address each of these multiple interacting social systems to reduce risk.

Compared with nonbinge trajectories, binge-drinking trajectories in adolescence, particularly frequent and chronic binge drinking, have been associated with poorer functioning in young adulthood. For example, youth in binge trajectories were more likely to have an alcohol or other drug use disorder in young adulthood than those in nonbinge trajectories (which may include abstainers and youth who drink, but do not report binge episodes, depending on the study).<sup>57,62,74,75</sup> In contrast, youth in nonbinge trajectories had better young-adult outcomes across domains such as educational attainment and employment, family and peer relations, and mental and physical health than did those in

binge trajectories, particularly those who engaged in frequent, chronic binge drinking.<sup>57,59,62,76</sup>

Other analyses have compared different binge-drinking trajectories (e.g., chronic vs. adolescent-limited). Such studies found that compared with adolescent-limited trajectories, chronic binge-drinking trajectories exhibited stronger associations with other substance use<sup>75</sup> and with stressful life events.<sup>63</sup> Further, compared with alcohol use that did not meet definitions of binge drinking (i.e., less than five drinks per occasion), adolescent binge drinking (five or more drinks per occasion) was associated with adverse outcomes, such as lower academic performance, greater likelihood of reporting drunk driving in the past month, and other substance use.<sup>58</sup> In sum, a pattern of relatively frequent and chronic binge drinking during adolescence, compared to nonbinge trajectories, was associated with worse young-adult outcomes across multiple domains, including risk for substance use disorder.

## Neurocognitive Consequences of Adolescent Binge Drinking

In the context of the ongoing brain maturation that occurs in adolescence and young adulthood,<sup>77,78</sup> binge drinking could result in potentially long-lasting neural alterations. For example, in rodent models, a binge pattern of alcohol exposure in adolescence has been associated with disrupted hippocampal functioning.<sup>79</sup> Further, animal models indicate that binge alcohol exposure during adolescence can have downstream effects on cognition and behavior through epigenetic mechanisms.<sup>80,81</sup> The specific effects of binge drinking during adolescence on the brain and neurocognition may depend on the timing, dose, and chronicity of alcohol exposure.<sup>38,82</sup>

Similar to animal research, in studies of human adolescents, heavy drinking has been associated with deficits in neuropsychological functioning<sup>83,84</sup>

and aberrations in brain structure and functioning.<sup>85-88</sup> Some research suggests possible gender-specific adverse consequences of binge alcohol consumption on neurocognition.<sup>89</sup> However, other research has found no difference between adolescent heavy drinkers (defined as 5+/6+ glasses, 10 g alcohol per glass, per occasion for females/males at least weekly) and light/nondrinkers in the maturation of basic executive functions (e.g., working memory).<sup>90</sup> Overall, binge drinking in human adolescents may have relatively subtle effects on neuropsychological measures at the level of behavioral performance; given relatively short drinking histories among youth, differences between young binge drinkers and their healthy counterparts more readily are observed at the level of brain structure and functioning.<sup>86</sup> Importantly, research suggests that after controlling for overall quantity of alcohol consumed, a binge pattern (i.e., consuming five or more drinks per occasion vs. consuming fewer than five drinks per occasion), in particular, was associated with adverse effects on brain functioning in young adults.<sup>91</sup>

Because most of the existing studies on binge drinking and neurocognition in human adolescents have been cross-sectional, the extent to which the findings reflect pre-existing characteristics or persistent (vs. possibly transient) consequences of heavy or binge alcohol use are unclear. However, emerging research suggests that aberrations in the brain circuitry underlying decision-making may not only signal risk for binge drinking in adolescence prior to heavy drinking<sup>92</sup> but also may be adversely affected by binge drinking in adolescence and young adulthood.<sup>93</sup> The reversibility of the effects of adolescent binge drinking on brain structure and functioning with sustained abstinence warrants study, particularly because brain maturation continues into young adulthood.<sup>78</sup> Large ongoing multisite studies, such as the National Consortium on Alcohol and Neurodevelopment in

Adolescence,<sup>94</sup> the IMAGEN study in Europe,<sup>95</sup> and the Adolescent Brain and Cognitive Development Study (<https://abcdstudy.org>), which are examining the effects of alcohol and other substance use on the developing brain in adolescence, are poised to address these gaps in knowledge.

## Implications for Prevention and Intervention

To reduce binge drinking, coordinated prevention and intervention efforts that operate across multiple levels (e.g., individual, family, community, and national policy), as well as continue across the life span, are needed.<sup>1,21</sup> Such prevention efforts should be timed to begin by late childhood and should be tailored to address risks most salient to specific developmental periods and individual circumstances. For example, gender differences in risk factors for underage drinking<sup>44,70</sup> suggest the potential utility of gender-specific interventions. Increasingly, developmental neuroscience provides the basis for novel prevention and intervention approaches that strengthen the social-emotional and decision-making skills needed to refrain from binge drinking, such as emotion regulation or resisting peer pressure to engage in risky behavior.<sup>95,96</sup> Additional interventions for youth are needed that address alcohol's strongly perceived positive effects. One approach may be to support alternative socially based rewarding and healthy activities, because experiencing adverse alcohol-related consequences may not reduce binge drinking in young populations.<sup>12</sup>

Ideally, prevention should include routine alcohol screening and brief intervention for all youth, as well as supportive guidance for parents and caregivers.<sup>97,98</sup> Community-based prevention and intervention programs have shown effects in reducing underage drinking.<sup>99</sup> School-based programs<sup>100</sup> and easy access to a continuum of services<sup>4</sup> are other examples



of community-level supports for youth and families. At the level of public policy, strong alcohol policy environments<sup>101</sup> and enhanced enforcement of local alcohol regulatory policies,<sup>102</sup> such as the minimum legal drinking age and social-hosting laws, have deterred underage drinking.<sup>4</sup>

## Conclusions

Adolescence is a critical period of risk for binge drinking. An adolescent-specific sensitivity to alcohol's effects may interact with a normative propensity for greater risk-taking behavior and peer social environment in contributing to risk for binge drinking during this developmental period. Although there is debate regarding the definition of a binge-drinking episode, a dose-response relationship between episodic high-quantity alcohol consumption and increased risk for adverse consequences generally has been observed.<sup>18-20</sup> Binge drinking in adolescence has been associated with multiple acute harms to health,<sup>4</sup> including possible effects of heavy drinking on neuropsychological functioning<sup>83,84,87</sup> and potential longer term adverse young-adult outcomes.<sup>57</sup> Of particular concern is emerging research with young adults, which suggests that certain negative consequences of alcohol use on neurocognition may be specific to a binge pattern of alcohol consumption.<sup>91</sup> Although the prevalence of adolescent binge drinking has declined since the 1970s, rates are still high. Moreover, binge-drinking prevalence likely is underestimated by surveys that use a binge definition of five or more drinks per occasion, because lower drinking-quantity thresholds to define binge drinking may be indicated, particularly for youth. Strategically coordinated prevention programs that operate across the life span and at multiple levels, ranging from individuals and families to public policy, are essential to reducing adolescent binge drinking.

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## References

1. Substance Abuse and Mental Health Services Administration (SAMHSA). *Report to Congress on the Prevention and Reduction of Underage Drinking*. Vol 1. Washington, DC: SAMHSA, U.S. Department of Health and Human Services; December 2013. <https://store.samhsa.gov/shin/content/PEP13-RTCUAD/PEP13-RTCUAD.pdf>. Accessed July 28, 2017.
2. Office of Juvenile Justice and Delinquency Prevention (OJJDP). *Drinking in America: Myths, Realities, and Prevention Policy*. Washington, DC: OJJDP, Office of Justice Programs, U.S. Department of Justice; 2005.
3. U.S. Department of Health and Human Services. *The Surgeon General's Call to Action to Prevent and Reduce Underage Drinking*. Washington, DC: U.S. Department of Health and Human Services; 2007. [http://www.camy.org/\\_docs/resources/fact-sheets/Call\\_To\\_Action.pdf](http://www.camy.org/_docs/resources/fact-sheets/Call_To_Action.pdf). Accessed July 28, 2017.
4. Hingson R, White A. New research findings since the 2007 Surgeon General's Call to Action to Prevent and Reduce Underage Drinking: A review. *J Stud Alcohol Drugs*. 2014;75(1):158-169. PMID: 24411808.
5. SAMHSA, Center for Behavioral Health Statistics and Quality. *Behavioral Health Trends in the United States: Results From the 2014 National Survey on Drug Use and Health*. Rockville, MD: U.S. Department of Health and Human Services; 2015. <https://www.samhsa.gov/data/sites/default/files/NSDUH-FRR1-2014/NSDUH-FRR1-2014.htm>. Accessed July 28, 2017.
6. Courtney KE, Polich J. Binge drinking in young adults: Data, definitions, and determinants. *Psychological Bul*. 2009;135(1):142-156. PMID: 19210057.
7. Gmel G, Kuntsche E, Rehm J. Risky single-occasion drinking: Bingeing is not bingeing. *Addiction*. 2011;106(6):1037-1045. PMID: 21564366.
8. National Institute on Alcohol Abuse and Alcoholism (NIAAA). NIAAA Council approves definition of binge drinking. *NIAAA Newsletter*. Winter 2004;(3):3.

[https://pubs.niaaa.nih.gov/publications/Newsletter/winter2004/Newsletter\\_Number3.pdf](https://pubs.niaaa.nih.gov/publications/Newsletter/winter2004/Newsletter_Number3.pdf). Accessed July 28, 2017.

9. Fillmore MT. Acute alcohol-induced impairment of cognitive functions: Past and present findings. *Int J Disabil Hum Dev*. 2011;6(2):115-126.
10. Dawson DA, Grant BF, Li TK. Quantifying the risks associated with exceeding recommended drinking limits. *Alcohol Clin Exp Res*. 2005;29(5):902-908. PMID: 15897737.
11. Donovan JE. Estimated blood alcohol concentrations for child and adolescent drinking and their implications for screening instruments. *Pediatrics*. 2009;123(6):e975-e981. PMID: 19482748.
12. Patrick ME. A call for research on high-intensity alcohol use. *Alcohol Clin Exp Res*. 2016;40(2):256-259. PMID: 26842244.
13. Patrick ME, Schulenberg JE, Martz ME, et al. Extreme binge drinking among 12th-grade students in the United States: Prevalence and predictors. *JAMA Pediatr*. 2013;167(11):1019-1025. PMID: 24042318.
14. White A, Kraus C, Swartzwelder H. Many college freshmen drink at levels far beyond the binge threshold. *Alcohol Clin Exp Res*. 2006;30(6):1006-1010. PMID: 16737459.
15. Beirness DJ, Foss RD, Vogel-Sprott M. Drinking on campus: Self-reports and breath tests. *J Stud Alcohol*. 2004;65(5):600-604. PMID: 15536769.
16. Perry PJ, Argo TR, Barnett MJ, et al. The association of alcohol-induced blackouts and grayouts to blood alcohol concentrations. *J Forensic Sci*. 2006;51(4):896-899. PMID: 16882336.
17. Miller JW, Naimi TS, Brewer RD, et al. Binge drinking and associated health risk behaviors among high school students. *Pediatrics*. 2007;119(1):76-85. PMID: 17200273.
18. Esser MB, Kanny D, Brewer RD, et al. Binge drinking intensity: A comparison of two measures. *Am J Prev Med*. 2012;42(6):625-629. PMID: 22608381.
19. Jackson KM. Heavy episodic drinking: Determining the predictive utility of five or more drinks. *Psychol Addictive Behav*. 2008;22(1):68-77. PMID: 18298232.
20. Read JP, Beattie M, Chamberlain R, et al. Beyond the "binge" threshold: Heavy drinking patterns and their association with alcohol involvement indices in college students. *Addict Behav*. 2008;33(2):225-234. PMID: 17997047.
21. Siqueira L, Smith VC, Committee on Substance Abuse. Binge drinking. *Pediatrics*. 2015;136(3):e718-e726. PMID: 26324872.
22. Chen CM, Yi HY, Faden VB. *Surveillance Report #101: Trends in Underage Drinking in the United States, 1991-2013*. Rockville, MD: U.S. Department of Health and Human Services; March 2015. <https://pubs.niaaa.nih.gov/publications/surveillance101/Underage13.pdf>. Accessed July 28, 2017.
23. SAMHSA, Center for Behavioral Health Statistics and Quality. *Behavioral Health Barometer: United States, 2015*. Rockville, MD: U.S. Department of Health and Human Services; 2015. <https://store.samhsa.gov/>

- shin/content/SMA16-BARO-2015/SMA16-BARO-2015.pdf. Accessed July 28, 2017.
24. Johnston LD, O'Malley PM, Miech RA, et al. *Monitoring the Future National Survey Results on Drug Use, 1975–2015: 2015 Overview, Key Findings on Adolescent Drug Use*. Ann Arbor, MI: Institute for Social Research, University of Michigan; 2016. <http://www.monitoringthefuture.org/pubs/monographs/mff-overview2015.pdf>. Accessed July 28, 2017.
  25. Kann L, Kinchen S, Shanklin SL, et al. Youth risk behavior surveillance—United States, 2013. *MMWR Suppl*. 2014;63(4):1-168. PMID: 24918634.
  26. SAMHSA, Center for Behavioral Health Statistics and Quality. *Results from the 2013 National Survey on Drug Use and Health: Summary of National Findings*. Rockville, MD: U.S. Department of Health and Human Services; 2014. <https://www.samhsa.gov/data/sites/default/files/NSDUHResultsPDFWHTML2013/Web/NSDUHResults2013.pdf>. Accessed July 28, 2017.
  27. Linkenbach J, Young DJ. Accounting for changes in alcohol use and abuse in the United States. *SAGE Open*. 2012;2(3):1-8. doi:10.1177/2158244012459742.
  28. SAMHSA, Center for Behavioral Health Statistics and Quality. *Results from the 2015 National Survey on Drug Use and Health: Detailed Tables*. Rockville, MD: U.S. Department of Health and Human Services; 2016. <https://www.samhsa.gov/data/sites/default/files/NSDUH-DefTabs-2015/NSDUH-DefTabs-2015/NSDUH-DefTabs-2015.pdf>. Accessed July 28, 2017.
  29. Kann L, McManus T, Harris WA, et al. Youth risk behavior surveillance—United States, 2015. *MMWR Surveill Summ*. 2016;65(6):1-174. PMID: 27280474.
  30. Hibell B, Guttormsson U, Ahlström S, et al. *The 2011 ESPAD Report—Substance Use Among Students in 36 European Countries*. Stockholm, Sweden: The Swedish Council for Information on Alcohol and Other Drugs; May 2012. [http://www.espad.org/sites/espad.org/files/The\\_2011\\_ESPAD\\_Report\\_FULL\\_2012\\_10\\_29.pdf](http://www.espad.org/sites/espad.org/files/The_2011_ESPAD_Report_FULL_2012_10_29.pdf). Accessed July 28, 2017.
  31. White V, Baroliola E. *Australian Secondary Students' Use of Tobacco, Alcohol and Over-the-Counter and Illicit Substances in 2011*. Victoria, Australia: Centre for Behavioral Research in Cancer, Cancer Council Victoria; 2012. [http://www.nationaldrugstrategy.gov.au/internet/drugstrategy/Publishing.nsf/content/BCBF6B2C638E1202CA257ACD0020E35C/\\$File/National%20Report\\_FINAL\\_ASSAD\\_7.12.pdf](http://www.nationaldrugstrategy.gov.au/internet/drugstrategy/Publishing.nsf/content/BCBF6B2C638E1202CA257ACD0020E35C/$File/National%20Report_FINAL_ASSAD_7.12.pdf). Accessed July 28, 2017.
  32. Simons-Morton B, Pickett W, Boyce W, et al. Cross-national comparison of adolescent drinking and cannabis use in the United States, Canada, and the Netherlands. *Int J Drug Policy*. 2010;21(1):64-69. PMID: 19303761.
  33. Johnston LD, O'Malley PM, Miech RA, et al. *Demographic Subgroup Trends Among Adolescents in the Use of Various Licit and Illicit Drugs, 1975–2014*. Ann Arbor, MI: Institute for Social Research, University of Michigan; 2015. *Monitoring the Future Occasional Paper 83*. <http://monitoringthefuture.org/pubs/occpapers/mtf-occ83.pdf>. Accessed July 28, 2017.
  34. White A, Castle IJ, Chen CM, et al. Converging patterns of alcohol use and related outcomes among females and males in the United States, 2002 to 2012. *Alcohol Clin Exp Res*. 2015;39(9):1712-1726. PMID: 26331879.
  35. SAMHSA, Center for Behavioral Health Statistics and Quality. *2012–2014 National Survey on Drug Use and Health National Maps of Prevalence Estimates, by Substate Region*. Rockville, MD: U.S. Department of Health and Human Services; 2015. <https://www.samhsa.gov/data/sites/default/files/NSDUHsubstateNationalMaps2014/NSDUHsubstateNationalMaps2014.htm>. Accessed July 28, 2017.
  36. Brown SA, McGue M, Maggs J, et al. A developmental perspective on alcohol and youths 16 to 20 years of age. *Pediatrics*. 2008;121(suppl 4):S290-S310. PMID: 18381495.
  37. Chung T, Jackson KM. Adolescent alcohol use. In: Brown S, Zucker RA, eds. *The Oxford Handbook of Adolescent Substance Abuse*. Oxford, UK: Oxford University Press; 2016. doi:10.1093/oxfordhb/9780199735662.013.007.
  38. Spear LP. Alcohol consumption in adolescence: A translational perspective. *Curr Addict Rep*. 2016;3:50-61. doi:10.1007/s40429-016-0088-9.
  39. Miranda R Jr, Monti PM, Ray L, et al. Characterizing subjective responses to alcohol among adolescent problem drinkers. *J Abnorm Psychol*. 2014;123(1):117-129. PMID: 24661164.
  40. Behar D, Berg CJ, Rapoport JL, et al. Behavioral and physiological effects of ethanol in high-risk and control children: A pilot study. *Alcohol Clin Exp Res*. 1983;7(4):404-410. PMID: 6318590.
  41. Patrick ME, Crouse JM, Fairlie AM, et al. Day-to-day variations in high-intensity drinking, expectancies, and positive and negative alcohol-related consequences. *Addict Behav*. 2016;58:110-116. PMID: 26922158.
  42. Schriber RA, Guyer AE. Adolescent neurobiological susceptibility to social context. *Dev Cogn Neurosci*. 2016;19:1-18. PMID: 26773514.
  43. Steinberg L. A social neuroscience perspective on adolescent risk-taking. *Dev Rev*. 2008;28(1):78-106. PMID: 18509515.
  44. Shulman EP, Harden KP, Chein JM, et al. Sex differences in the developmental trajectories of impulse control and sensation-seeking from early adolescence to early adulthood. *J Youth Adolesc*. 2015;44(1):1-17. PMID: 24682958.
  45. Frieze B, Grube JW, Moore RS. Youth acquisition of alcohol and drinking contexts: An in-depth look. *J Drug Educ*. 2013;43(4):385-403. PMID: 25445811.
  46. Mayer RR, Forster JL, Murray DM, et al. Social settings and situations of underage drinking. *J Stud Alcohol*. 1998;59(2):207-215. PMID: 9500308.
  47. Hong T, Beaudoin CE, Johnson C. A panel study of peer norms and adolescent alcohol consumption: Developing strategies for communication interventions. *J Health Commun*. 2013;18(8):913-930. PMID: 23767700.
  48. Naimi TS, Siegel M, DeJong W, et al. Beverage- and brand-specific binge alcohol consumption among underage youth in the U.S. *J Subst Use*. 2015;20(5):333-339. PMID: 26425112.
  49. Maldonado-Molina MM, Reingle JM, Tobler AL, et al. Effects of beverage-specific alcohol consumption on drinking behaviors among urban youth. *J Drug Educ*. 2010;40(3):265-280. PMID: 21313986.
  50. White AM, Kraus CL, Flom JD, et al. College students lack knowledge of standard drink volumes: Implications for definitions of risky drinking based on survey data. *Alcohol Clin Exp Res*. 2005;29(4):631-638. PMID: 15834229.
  51. Mair C, Lippman-Kreda S, Gruenewald PJ, et al. Adolescent drinking risks associated with specific drinking contexts. *Alcohol Clin Exp Res*. 2015;39(9):1705-1711. PMID: 26208252.
  52. National Research Council, Institute of Medicine. *Reducing Underage Drinking: A Collective Responsibility*. Washington, DC: National Academies Press; 2004. <https://www.nap.edu/catalog/10729/reducing-underage-drinking-a-collective-responsibility>. Accessed July 28, 2017.
  53. Donovan JE, Molina BS. Types of alcohol use experience from childhood through adolescence. *J Adolesc Health*. 2013;53(4):453-459. PMID: 23763961.
  54. SAMHSA. *Binge Drinking: Terminology and Patterns of Use*. Rockville, MD: U.S. Department of Health and Human Services; 2016. <https://www.samhsa.gov/capt/tools-learning-resources/binge-drinking-terminology-patterns>. Accessed July 28, 2017.
  55. Kuntsche E, Rössow I, Simons-Morton B, et al. Not early drinking but early drunkenness is a risk factor for problem behaviors among adolescents from 38 European and North American countries. *Alcohol Clin Exp Res*. 2013;37(2):308-314. PMID: 23240610.
  56. Morean ME, Kong G, Camenga DR, et al. First drink to first drunk: Age of onset and delay to intoxication are associated with adolescent alcohol use and binge drinking. *Alcohol Clin Exp Res*. 2014;38(10):2615-2621. PMID: 25257574.
  57. Chassin L, Pitts SC, Prost J. Binge drinking trajectories from adolescence to emerging adulthood in a high-risk sample: Predictors and substance abuse outcomes. *J Consult Clin Psychol*. 2002;70(1):67-78. PMID: 11860058.
  58. D'Amico EJ, Metrik J, McCarthy DM, et al. Progression into and out of binge drinking among high school students. *Psychol Addict Behav*. 2001;15(4):341-349. PMID: 11767267.
  59. Hill KG, White HR, Chung IJ, et al. Early adult outcomes of adolescent binge drinking: Person- and variable-centered analyses of binge drinking trajectories. *Alcohol Clin Exp Res*. 2000;24(6):892-901. PMID: 10888080.
  60. Martino SC, Ellickson PL, McCaffrey DF. Multiple trajectories of peer and parental influence and their association with the development of adolescent heavy drinking. *Addict Behav*. 2009;34(8):693-700. PMID: 19423232.

61. Modecki KL, Barber BL, Eccles JS. Binge drinking trajectories across adolescence: For early maturing youth, extra-curricular activities are protective. *J Adolesc Health*. 2014;54(1):61-66. PMID: 24060575.
62. Tucker JS, Orlando M, Ellickson PL. Patterns and correlates of binge drinking trajectories from early adolescence to young adulthood. *Health Psychol*. 2003;22(1):79-87. PMID: 12558205.
63. Windle M, Mun EY, Windle RC. Adolescent-to-young adulthood heavy drinking trajectories and their prospective predictors. *J Stud Alcohol*. 2005;66(3):313-322. PMID: 16047520.
64. Zucker RA, Hicks BM, Heitzeg MM. Alcohol use and the alcohol use disorders over the life course: A cross-level developmental review. In: Cicchetti D, ed. *Developmental Psychopathology*. 3rd ed. Vol 3. New York, NY: Wiley & Sons; 2016:793-832.
65. Bronfenbrenner U. *The Ecology of Human Development*. Cambridge MA: Harvard University Press; 1979.
66. Clark TT, Yang C, McCleron FJ, et al. Racial differences in parenting style typologies and heavy episodic drinking trajectories. *Health Psychol*. 2015;34(7):697-708. PMID: 25222086.
67. Hahm HC, Kolaczek E, Jiang J, et al. Binge drinking trajectories from adolescence to young adulthood: The effects of peer social network. *Subst Use Misuse*. 2012;47(6):745-756. PMID: 22452735.
68. Leung RK, Toumbourou JW, Hemphill SA. The effect of peer influence and selection processes on adolescent alcohol use: A systematic review of longitudinal studies. *Health Psychol Rev*. 2014;8(4):426-457. PMID: 25211209.
69. Mundt M. Social network analysis of peer effects on binge drinking among U.S. adolescents. In: Greenberg A, Kennedy W, Bos N, eds. *Social Computing, Behavioral-Cultural Modeling and Prediction*. Berlin, Germany: Springer; 2013:123-134.
70. Hammerslag LR, Gulley JM. Sex differences in behavior and neural development and their role in adolescent vulnerability to substance use. *Behav Brain Res*. 2016;298(pt A):15-26. PMID: 25882721.
71. Shih RA, Mullins L, Ewing BA, et al. Associations between neighborhood alcohol availability and young adolescent alcohol use. *Psychol Addict Behav*. 2015;29(4):950-959. PMID: 26415057.
72. Lo CC, Weber J, Cheng TC. A spatial analysis of student binge drinking, alcohol-outlet density, and social disadvantages. *Am J Addict*. 2013;22(4):391-401. PMID: 23795880.
73. Paschall MJ, Lipperman-Kreda S, Grube JW. Effects of the local alcohol environment on adolescents' drinking behaviors and beliefs. *Addiction*. 2014;109(3):407-416. PMID: 24320952.
74. Olsson CA, Romaniuk H, Salinger J, et al. Drinking patterns of adolescents who develop alcohol use disorders: Results from the Victorian Adolescent Health Cohort Study. *BMJ Open*. 2016;6(2):e010455. PMID: 26868948.
75. Tucker JS, Ellickson PL, Orlando M, et al. Substance use trajectories from early adolescence to emerging adulthood: A comparison of smoking, binge drinking, and marijuana use. *J Drug Issues*. 2005;35(2):307-332.
76. Oesterle S, Hill KG, Hawkins JD, et al. Adolescent heavy episodic drinking trajectories and health in young adulthood. *J Stud Alcohol*. 2004;65(2):204-212. PMID: 15151351.
77. Casey BJ. Beyond simple models of self-control to circuit-based accounts of adolescent behavior. *Ann Rev Psychol*. 2015;66:295-319. PMID: 25089362.
78. Vertes PE, Bullmore ET. Annual research review: Growth connectomics—the organization and reorganization of brain networks during normal and abnormal development. *J Child Psychol Psychiatry*. 2015;56(3):299-320. PMID: 25441756.
79. White AM, Swartzwelder HS. Hippocampal function during adolescence: A unique target of ethanol effects. *Ann NY Acad Sci*. 2004;1021:206-220. PMID: 15251891.
80. Guerri C, Pascual M. Mechanisms involved in the neurotoxic, cognitive, and neurobehavioral effects of alcohol consumption during adolescence. *Alcohol*. 2010;44(1):15-26. PMID: 20113871.
81. Pandey SC, Sakharkar AJ, Tang L, et al. Potential role of adolescent alcohol exposure-induced amygdaloid histone modifications in anxiety and alcohol intake during adulthood. *Neurobiol Dis*. 2015;82:607-619. PMID: 25814047.
82. Spear LP. Adolescent alcohol exposure: Are there separable vulnerable periods within adolescence? *Physiol Behav*. 2015;148:122-130. PMID: 25624108.
83. Jacobus J, Taper SF. Neurotoxic effects of alcohol in adolescence. *Ann Rev Clin Psychol*. 2013;9:703-721. PMID: 23245341.
84. Lisdahl KM, Gilbart ER, Wright NE, et al. Dare to delay? The impacts of adolescent alcohol and marijuana use onset on cognition, brain structure, and function. *Front Psychiatry*. 2013;4:53. PMID: 23847550.
85. Feldstein Ewing SW, Sakhardande A, Blakemore SJ. The effect of alcohol consumption on the adolescent brain: A systematic review of MRI and fMRI studies of alcohol-using youth. *Neuroimage Clin*. 2014;5:420-437. PMID: 26958467.
86. Hermens DF, Lagopoulos J, Tobias-Webb J, et al. Pathways to alcohol-induced brain impairment in young people: A review. *Cortex*. 2013;49(1):3-17. PMID: 22789780.
87. Petit G, Mauraige P, Kornreich C, et al. Binge drinking in adolescents: A review of neurophysiological and neuro-imaging research. *Alcohol*. 2014;49(2):198-206. PMID: 24302160.
88. Squeglia LM, Tapert SF, Sullivan EV, et al. Brain development in heavy-drinking adolescents. *Am J Psychiatry*. 2015;172(6):531-542. PMID: 25982660.
89. Squeglia LM, Sorg SF, Schweinsburg AD, et al. Binge drinking differentially affects adolescent male and female brain morphometry. *Psychopharmacology (Berl)*. 2012;220(3):529-539. PMID: 21952669.
90. Boelema SR, Harakeh Z, van Zandvoort MJ, et al. Adolescent heavy drinking does not affect maturation of basic executive functioning: Longitudinal findings from the TRAILS study. *PLoS One*. 2015;10(10):e0139186. PMID: 26489080.
91. Mauraige P, Joassin F, Speth A, et al. Cerebral effects of binge drinking: Respective influences of global alcohol intake and consumption pattern. *Clin Neurophysiol*. 2012;123(5):892-901. PMID: 22055841.
92. Heitzeg MM, Cope LM, Martz ME, et al. Neuroimaging risk markers for substance abuse: Recent findings on inhibitory control and reward system functioning. *Curr Addict Rep*. 2015;2(2):91-103. PMID: 26236575.
93. Jones SA, Cservenka A, Nagel BJ. Binge drinking impacts dorsal striatal response during decision making in adolescents. *Neuroimage*. 2016;129:378-388. PMID: 26826511.
94. Brown SA, Brumbach T, Tomlinson K, et al. The National Consortium on Alcohol and Neurodevelopment in Adolescence (NCANDA): A multisite study of adolescent development and substance use. *J Stud Alcohol Drugs*. 2015;76(6):895-908. PMID: 26562597.
95. Conrod P, Nikolaou K. Annual research review: On the developmental neuropsychology of substance use disorders. *J Child Psychol Psychiatry*. 2016;57(3):371-394. PMID: 26889898.
96. Riggs NR. Translating developmental neuroscience to substance use prevention. *Curr Addict Rep*. 2015;2(2):114-121. PMID: 26236576.
97. NIAAA. *Alcohol Screening and Brief Intervention for Youth: A Practitioner's Guide*. Rockville, MD: NIAAA, U.S. Department of Health and Human Services; 2011. <https://pubs.niaaa.nih.gov/publications/Practitioner/YouthGuide/YouthGuide.pdf>. Accessed July 28, 2017.
98. Patton R, Deluca P, Kaner E, et al. Alcohol screening and brief intervention for adolescents: The how, what and where of reducing alcohol consumption and related harm among young people. *Alcohol*. 2014;49(2):207-212. PMID: 24232178.
99. Saltz RF, Grube JW, Treno AJ. Lessons from comprehensive environmental community prevention trials. In: Scheier LM, ed. *Handbook of Adolescent Drug Use Prevention: Research, Intervention Strategies, and Practice*. Washington, DC: American Psychological Association; 2015:313-328.
100. Foxcroft DR, Tsertsvadze A. Universal alcohol misuse prevention programmes for children and adolescents: Cochrane systematic reviews. *Perspect Public Health*. 2012;132(3):128-134. PMID: 22700577.
101. Xuan Z, Blanchette JG, Nelson TF, et al. Youth drinking in the United States: Relationships with alcohol policies and adult drinking. *Pediatrics*. 2015;136(1):18-27. PMID: 26034246.
102. Flewelling RL, Grube JW, Paschall MJ, et al. Reducing youth access to alcohol: Findings from a community-based randomized trial. *Am J Community Psychol*. 2013;51(1-2):264-277. PMID: 22688848.