

Associations between solitary drinking and increased alcohol consumption, alcohol problems, and drinking to cope motives in adolescents and young adults: a systematic review and meta-analysis

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ABSTRACT

Background and aims Emerging evidence suggests that solitary drinking may be an important early risk marker for alcohol use disorder. The current paper is the first meta-analysis and systematic review on adolescent and young adult solitary drinking to examine associations between solitary drinking and increased alcohol consumption, alcohol problems, and drinking to cope motives. **Methods** PsychINFO, PubMed, and Google Scholar were searched using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology and a pre-registered International Prospective Register of Systematic Reviews (PROSPERO) protocol (no. CRD42020143449). Data from self-report questionnaires regarding negative correlates of solitary drinking (e.g. alcohol problems) and solitary drinking motives (e.g. drinking to cope) were pooled across studies using random-effects models. Studies included adolescents (aged 12–18 years) and young adults (mean age between 18 and 30 years or samples with the majority of participants aged 30 years or younger). **Results** Meta-analytical results from 21 unique samples including 28,372 participants showed significant effects for the associations between solitary drinking and the following factors: increased alcohol consumption, $r = 0.23$, 95% confidence interval (CI) = 0.12, 0.33; drinking problems, $r = 0.23$, 95% CI = 0.13, 0.32; negative affect, $r = 0.21$, 95% CI = 0.16, 0.26; social discomfort, $r = 0.17$, 95% CI = 0.06, 0.27; negative reinforcement, $r = 0.28$, 95% CI = 0.24, 0.31; and positive reinforcement, $r = 0.10$, 95% CI = 0.03, 0.17. These associations were not moderated by age group (i.e. adolescent versus young adult), study quality, or differing solitary drinking definitions. Accounting for publication bias increased the effect sizes from $r = 0.23$ to 0.34 for alcohol consumption and from $r = 0.23$ to 0.30 for drinking problems, and lowered it from $r = 0.10$ to 0.06 and $r = 0.17$ to 0.11 for positive reinforcement and social discomfort, respectively. **Conclusions** Solitary drinking among adolescents and young adults appears to be associated with psychosocial/alcohol problems and drinking to cope motives.

Keywords Adolescents, alcohol use disorder risk, drinking alone, drinking to cope, meta-analysis, social drinking context, solitary drinking, systematic review, tension reduction, young adults.

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INTRODUCTION

Most adolescents and young adults who drink alcohol do so in social settings [1–4], with far fewer drinking alcohol while alone (e.g. [5,6]). However, an emerging literature suggests that solitary drinking in younger individuals may represent an informative divergence from normative behavior, with important implications for understanding risk for alcohol use disorder (AUD). For example,

adolescent and young adult solitary (versus social-only) drinkers often report increased alcohol consumption and more alcohol-related problems (e.g. [7–9]). While solitary drinking appears to be a risky drinking pattern for adolescents and young adults, no prior studies have meta-analyzed results across studies. The current study is the first, to our knowledge, to do so, providing a critical evaluation of the strength and reliability of these effects across studies.

If solitary drinking is a reliable marker for alcohol problems among adolescents and young adults, it will be important to understand why individuals drink alone, as such information may help to inform future intervention/prevention programs. One theory put forth in the literature is that adolescents and young adults drink alone to self-medicate with alcohol to alleviate or cope with negative affect (NA) (e.g. [7,8,10,11]). Consistent with this motivational model of alcohol use [4,11–13] in which individuals drink alcohol to regulate NA, studies suggest that drinking to cope motives are associated with solitary drinking in both adolescents (e.g. [11]) and young adults (e.g. [9]). In fact, among these individuals, increased solitary drinking frequency is associated with increased NA [14] and NA-inducing experiences/states (e.g. loneliness) [15], which may make these individuals particularly likely to drink alcohol to cope.

A recent narrative review on solitary drinking in US adolescents emphasized the association between solitary drinking and coping with NA [16]. It is unclear how reliable these effects are across studies, however, as quantitative analyses were not conducted. In addition, to lend credence to the theory that solitary drinking is motivated by the desire to ameliorate NA, it is important to evaluate whether solitary drinking is not also associated with positive reinforcement (e.g. enhancement motives). Specifying the exact motives underlying solitary drinking (i.e. negative versus positive reinforcement) is necessary to develop effective treatment approaches. Finally, this prior narrative review [16] focused exclusively on adolescents, but young adulthood is also a period of particular risk for alcohol misuse [17] and solitary drinking has been associated with problematic outcomes in this group, as well (e.g. [15,18]). A meta-analytical strategy will allow us to determine the relative importance of solitary drinking in predicting problematic alcohol use throughout these two age periods.

The current meta-analysis is the first, to our knowledge, to provide quantitative analyses on (1) whether adolescent and young adult solitary drinking is associated with increased alcohol involvement and more alcohol-related problems and (2) whether the desire to cope with NA [versus a desire to enhance positive affect (PA)] is associated with solitary drinking. Because adolescence and young adulthood are unique periods of development with differences across a variety of domains (e.g. physically, socially [19,20]), including differences in drinking experiences (e.g. legal access to alcohol), age group was included as a moderator in analyses. We also conducted a systematic review examining the prevalence rates of and demographic factors associated with solitary drinking in adolescents and young adults and other related negative psychosocial outcomes. This information will increase our understanding of which adolescents and young adults are especially vulnerable to drink alone.

We hypothesized that solitary drinking would be associated with greater alcohol consumption and alcohol-related problems. Consistent with motivational models of alcohol use [4,11–13], we also predicted that solitary drinking would be associated with greater NA (e.g. depressive symptoms), more NA-inducing social experiences (e.g. loneliness, social anxiety) and negative (but not positive) reinforcement (e.g. drinking to cope). We begin by defining solitary drinking and reviewing how it has been measured. Next, we present prevalence rates and associated demographics of solitary drinking in adolescents and young adults. We finally review and meta-analyze the negative correlates and consequences of solitary drinking and motives associated with drinking alone, specifically highlighting the association between drinking to cope motives and solitary drinking.

METHOD

We adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) methodology [21]. The full review protocol is available in International Prospective Register of Systematic Reviews (PROSPERO); <http://www.crd.york.ac.uk/PROSPERO/>), registration no. CRD42020143449.

The following electronic databases were searched for studies in December 2018 and again in June 2019: Google Scholar, psycINFO, and PubMed. Search terms were (alcohol or drinking) and (solitary, alone, or non-social) and (young adult, emerging adult, adolescent). The reference lists of identified studies were also scanned, and reverse searches were generated and scanned for appropriate studies. Articles were included in both the systematic review and meta-analysis if solitary drinking was assessed in a sample of adolescents (aged 12–18 years) or young adults (mean ages = 18–30 or samples with the majority of participants ≤ age 30).

To be included in the meta-analysis, studies were required to measure negative correlates or consequences of solitary drinking or motives for drinking alone (see below for more information). To be included in the systematic review, studies had to report prevalence rates of drinking alone, associated demographic factors or negative psychosocial outcomes, or examine in-the-moment affective experiences while drinking alone. Exclusionary criteria for both reviews included non-human animals and non-English language.

Data extraction, coding, and statistical analysis

For the meta-analysis, we extracted statistics (i.e. correlations, means, odds ratios) relevant for understanding the relationships between solitary drinking and the following superordinate factors: ‘alcohol consumption’, ‘drinking

problems', 'negative affect', 'social discomfort', 'negative reinforcement', and 'positive reinforcement' (see Table 1). When these statistics were not available, we requested them from authors.¹ A second member of the study team independently extracted these data, which resulted in excellent reliability (inter-rater agreement = 97%). The few discrepancies that existed were reconciled by team discussion. Analyses were run using Comprehensive Meta Analysis (CMA version 2.0) software [22], and final effect sizes are reported as Pearson's *r*.

Each value contributing to an aggregate effect size was independent of all other values. When studies included multiple ways of assessing solitary drinking (e.g. frequency and quantity [15]), to be conservative we included the solitary drinking variable with the weakest association. When studies reported associations between solitary drinking and multiple variables categorized within the same superordinate factor (e.g. depression and hopelessness, which were both included in the 'negative affect' superordinate factor), we computed an average effect size across the variables [22,23]. Finally, results from studies reporting on the same sample were averaged over and treated as a single study.

Random-effects models were used for all analyses [24]. The heterogeneity of effect sizes across studies for each superordinate factor was tested with the *Q* statistic [22,23]. When the heterogeneity test was significant, we tested for potential moderation by (1) age group (i.e. adolescent versus young adult), (2) differing solitary drinking definitions, and (3) study quality. Studies were coded as 'alone' if solitary drinking was defined as drinking while physically alone and 'all others' if it was defined as drinking with non-drinking or non-interacting others.² Study quality was assessed using the system outlined by Mason [16]. Each study was coded on three study features (i.e. representative sampling, standardized measurement, and prospective longitudinal analysis) and received a score of 0–3, depending on the absence/presence (0/1) of each feature. The average study quality rating across studies was 1.44 [standard deviation (SD) = 0.78], with the majority of studies receiving a score of 1 (37%) or 2 (46%) (see Table 2). Publication bias was evaluated by Begg's rank correlation test [25], funnel plots to visualize bias, and trim-and-fill methods [26].

RESULTS

A total of 528 articles were identified in the search. Fifty-eight articles were included in the systematic review;

28 articles with 21 unique samples ($n = 28,372$ individuals) were included in the meta-analysis (see Fig. 1 for a PRISMA diagram).

Definitions and measures of solitary drinking

Definitions and measures of solitary drinking varied across studies (see Table 2). Solitary drinking was defined in most studies as drinking while alone (i.e. drinking without others present) (e.g. [7,8,10]). In some studies, solitary drinking also included drinking with non-drinking others (e.g. [6,18,27]) and/or among non-interacting others (e.g. [28–31]). Measures of solitary drinking also differed across studies. Researchers often dichotomized solitary drinking as presence or absence of this versus social-only drinking (e.g. [5,6]), but some also reported solitary drinking quantity (e.g. [15]), frequency (e.g. [14,32]) and/or frequency of heavy solitary drinking (e.g. [9,15]). Alternatively, other researchers assessed solitary drinking as a percentage of total drinking episodes (e.g. [7,8,10]). Importantly, the latter may decrease confounding overall drinking frequency with solitary drinking (i.e. those who drink more often, have more opportunities to drink in social and solitary settings), which can be problematic when only inquiring about solitary drinking frequency.

Prevalence rates

Prevalence rates of solitary drinking varied among studies, but generally the majority of adolescents and young adults did not report drinking alone. According to a recent review [16], 14% of the general US adolescent population reported drinking alone, but this increased to almost 40% among high-risk subgroups (i.e. clinical). Interestingly, some studies reported lower prevalence rates (< 14%) of adolescent solitary drinking [33–38], but this may be due to the use of non-US samples [34,38], or the measurement utilized (e.g. last drinking context) [33,35–37].

Among young adults, prevalence rates of solitary drinking also varied, ranging from approximately 15 to 24%, regardless of how solitary drinking was defined (e.g. [6,18,39]). However, prevalence rates of solitary drinking in on-line samples [7], as well as samples that included heavy drinkers [9,15,27] and those with suicidal ideation [9] or depressive symptomology [27] were higher, ranging from 24 to 74%.

Demographics

Findings on demographic variables associated with solitary drinking were mixed. Some studies found that adolescents

¹Data were obtained for 12 independent samples, data no longer existed for 13 samples, two authors did not respond to multiple queries, and two authors stated it was too difficult to extract the requested data.

²We also conducted the meta-analysis omitting studies that defined solitary drinking as anything other than drinking while alone, and results were similar.

Table 1 Superordinate factors and underlying variables of interest.

<i>Study authors</i>	<i>Superordinate factor</i>	<i>Variables of interest included</i>	<i>Scale/questionnaires</i>
	Alcohol consumption		
Anderson & Brown 2010		Binge drinking General drinking frequency Life-time drinking frequency Maximum drinking quantity	Frequency 5+ drinks/past month Times/past month Times/life Max. drinks/occasion/past month
Armeli <i>et al.</i> 2016 ^a		Drinking frequency Heavy drinking frequency	Days/past month Heavy drinking days/past month
Armeli <i>et al.</i> 2018		Drinking quantity	Drinks/day
Blevins <i>et al.</i> 2018		Drinking quantity Drinking frequency	DDQ DDQ
Buckner & Terlecki 2016		Drinking frequency	DDQ
Christiansen, Vik & Jarchow 2002		Drinking frequency Heavy drinking frequency Drinking quantity	CDDR Max. drinks past 3 months CDDR
Creswell <i>et al.</i> 2014		Drinking quantity Drinking frequency	LDHM LDHM
Creswell <i>et al.</i> 2015		Drinking frequency Drinking quantity	LDHM LDHM
Falcon <i>et al.</i> 2014		Binge drinking	Presence/absence 5+ drinks on last drinking occasion
Gonzalez, Collins & Bradizza 2009		Drinking quantity	NIAAA
Keough <i>et al.</i> 2015		Quantity × frequency	Days/week × drinks/occasion
Keough <i>et al.</i> 2016		Quantity × frequency	Days/week × drinks/occasion
O'Hara <i>et al.</i> 2014		Drinking quantity Heavy drinking frequency	Drinks/day Presence/absence 4/5+ drinks/day
O'Hara <i>et al.</i> 2015		Drinking frequency Drinking quantity Binge drinking	Days/past month Drinks/day/past 3 months Days 4/5+ drinks consumed/past month
Skrzynski <i>et al.</i> 2018		Drinking frequency Drinking quantity	NIAAA NIAAA
Stewart & Powers 2003		Drinking frequency Heavy drinking frequency Drinking quantity	Days/past month and days/per year Number of days large quantity consumed Typical drinks/occasion
Terry-McElrath, Stern & Patrick 2017		Maximum drinking quantity	Max drinks/occasion
Tucker <i>et al.</i> 2006		Drinking frequency Drinking quantity	Times/year and times/month Drinks/day
Tucker <i>et al.</i> 2014		Drinking quantity	At least 1 drink/past month
Williams, Vik & Wong 2015		Drinking quantity	CDDR
	Drinking problems		
Anderson & Brown 2010		Drinking problems	CHKS
Armeli <i>et al.</i> 2018		Drinking problems	B-YAACQ
Beck, Ahmad & Farkas 2011		Drinking problems Drinking problems	Driving after drinking Drinking after drinking too much
Bilevicious <i>et al.</i> 2018		Drinking problems	AUDIT
Buckner & Terlecki 2016		Drinking problems	RAPI
Christiansen, Vik & Jarchow 2002		Drinking problems	Questions adapted from studies by Wechsler ^c
Creswell <i>et al.</i> 2014		Drinking problems	AUD symptoms at age 25 from SCID-IV
Gonzalez, Collins & Bradizza 2009		Drinking problems	YAACQ

(Continues)

Table 1. (Continued)

<i>Study authors</i>	<i>Superordinate factor</i>	<i>Variables of interest included</i>	<i>Scale/questionnaires</i>
Gonzalez & Skewes 2013		Drinking problems	SADD
Keough <i>et al.</i> 2015		Drinking problems	RAPI
Keough <i>et al.</i> 2016		Drinking problems	RAPI
Keough <i>et al.</i> 2018		Drinking problems	YAACQ
		Drinking problems	AUDIT-C
Skrzynski <i>et al.</i> 2018		Drinking problems	AUDIT
		Drinking problems	B-YAACQ
Stewart & Powers 2003		Drinking problems	Negative consequences from drinking
Tucker <i>et al.</i> 2014		Drinking problems	Negative consequences from drinking
West, Drummond & Eames 1990		Drinking problems	Experiencing/perpetrating trouble
Williams, Vik & Wong 2015		Drinking problems	MAST
			CDDR
			DSM-IV alcohol dependence
	Negative affect (NA)		
Anderson & Brown 2010		Negative temperament	Negative Temperament Scale
Armeli <i>et al.</i> 2016 ^a		Anger/anxiety/depressive affect	PANAS
		Daily stress	Question rating day's overall stressfulness
		Neuroticism	NEO-PI-R
Armeli <i>et al.</i> 2018		Anger/anxiety/depressive affect	PANAS/Larsen & Diener mood circumplex
		Life stress	PERI life events scale
Bilevicious <i>et al.</i> 2018		Depression	CES-D
		Anxiety	GAD-7
Christiansen, Vik & Jarchow 2002		Depression	CES-D
Creswell <i>et al.</i> 2015		Aggression	MPQ
		Alienation	MPQ
		Stress reaction	MPQ
Gonzalez 2012		Previous suicidal behavior	SBQ-R
Gonzalez & Skewes 2013		Depression	BDI-II
		Hopelessness	BHS
		Suicidal ideation	ASIQ
Gonzalez, Collins & Bradizza 2009		Depression	BDI-II
		Suicidal ideation	ASIQ
Keough <i>et al.</i> 2015		Depression	MASQ-AD
O'Hara <i>et al.</i> 2015		Anger/anxiety/depressive affect	PANAS
	Social discomfort		
Buckner & Terlecki 2016		Social anxiety	SIAS
Gonzalez & Skewes 2013		Loneliness	UCLA
		Social competence	SCQ
		Social network satisfaction	Individual question
		Social support-seeking	CSI-SS
		Social withdrawal	CSI-SW
Keough <i>et al.</i> 2016		Social anxiety	SIAS
Skrzynski <i>et al.</i> 2018		Loneliness	UCLA
		Perceived social support—appraisal	ISEL
		Perceived social support—belonging	ISEL
		Social anxiety	SIAS

(Continues)

Table 1. (Continued)

<i>Study authors</i>	<i>Superordinate factor</i>	<i>Variables of interest included</i>	<i>Scale/questionnaires</i>
	Negative reinforcement		
Armeli <i>et al.</i> 2016		Drinking to cope	DMQ-R ^b
Armeli <i>et al.</i> 2018		Drinking to cope	DMQ-R ^b
Beck, Ahmad & Farkas 2011		Drinking to cope with emotional pain	Social context of drinking (Beck <i>et al.</i> 2008)
Blevins Abrantes & Stephens 2018		Drinking to cope Drinking during unpleasant emotion	DMQ-R IDS
Christiansen, Vik & Jarchow 2002		Drinking refusal self-efficacy during NA Personal coping expectancies Social coping expectancies	DRSE-ER AEQ AEQ
Creswell <i>et al.</i> 2014		Drinking during unpleasant emotion	IDS
Creswell <i>et al.</i> 2015		Drinking refusal self-efficacy during NA	SCQA
Gonzalez & Skewes 2013		Drinking to cope	Drinking context scale
Gonzalez, Collins & Bradizza 2009		Drinking to cope	DMQ-R
O'Hara <i>et al.</i> 2014		Drinking to cope	DMQ-R ^b
O'Hara, Armeli & Tennen 2015		Drinking to cope	DMQ-R ^b /MDMQ-R
Skrzynski <i>et al.</i> 2018		Drinking to cope Drinking refusal self-efficacy during NA	DMQ-R DRSE-ER
Stewart & Powers 2003		Drinking to cope	Drinking reasons related to coping
Terry-McElrath <i>et al.</i> 2017		Drinking to cope	Drinking reasons related to coping
Tucker <i>et al.</i> 2014		Negative outcome expectancies	2 items from drinking expectancies scale (Ellickson <i>et al.</i> 2003)
Williams, Vik & Wong 2015		Drinking to cope	DMQ-R
	Positive reinforcement		
Armeli <i>et al.</i> 2016		Drinking to enhance	DMQ-R ^b
Armeli <i>et al.</i> 2018		Drinking to enhance	DMQ-R ^b
Beck, Ahmad & Farkas 2011		Drinking to socialize/have a good time	Social context of drinking (Beck <i>et al.</i> 2008)
Blevins, Abrantes & Stephens 2018		Drinking to socialize Drinking to enhance Drinking during pleasant emotion Drinking during pleasant times with others	DMQ-R DMQ-R IDS IDS
Christiansen, Vik & Jarchow 2002		Personal enhancement expectancies Social enhancement expectancies	AEQ AEQ
Creswell <i>et al.</i> 2014		Drinking during pleasant emotion	IDS
Gonzalez, Collins & Bradizza 2009		Drinking to enhance Drinking to socialize	DMQ-R DMQ-R
O'Hara <i>et al.</i> 2014		Drinking to enhance	DMQ-R ^b

(Continues)

Table 1. (Continued)

Study authors	Superordinate factor	Variables of interest included	Scale/questionnaires
O'Hara, Armeli & Tennen 2015		Drinking to socialize	DMQ-R ^b
Stewart & Powers 2003		Drinking to socialize	DMQ-R ^b
Terry-McElrath <i>et al.</i> 2017		Drinking to enhance	DMQ-R ^b
Tucker <i>et al.</i> 2014		Drinking to socialize	Drinking reasons related to being social
		Drinking to socialize	Drinking reasons related to being social
		Positive outcome expectancies	1 item from drinking expectancies scale (Ellickson <i>et al.</i> 2003)

DDQ = Daily drinking questionnaire; CDDR = customary drinking and drug use record; LDHM = life-time drinking history method; NIAAA = National Institute of Alcohol Abuse and Alcoholism alcohol consumption question set; CHKS = California Healthy Kids Survey; (B-)YAACQ = (Brief) Young adult alcohol consequences questionnaire; AUDIT = Alcohol Use Disorder Identification Test; RAPI = Rutgers Alcohol Problem Index; SCID-IV = Structured Clinical Interview for the DSM-IV; SADD = short alcohol dependence data; MAST = Michigan Alcohol Screening Test; PANAS = Positive and Negative Affective Scale; NEO-PI-R = neuroticism extroversion openness–personality inventory—revised; CES-D = Center for Epidemiologic Studies—depression; GAD-7 = Generalized Anxiety Disorder scale; MPQ = Multidimensional Personality Questionnaire; SBQ-R = the Suicidal Behaviors Questionnaire—Revised; BDI-II = Beck Depression Inventory-II; BHS = Beck Hopelessness Scale; ASIQ = Adult Suicidal Ideation Questionnaire; MASQ-AD = Mood and Anxiety Symptom Questionnaire—anhedonic depression subscale; SIAS = Social Interaction and Anxiety Scale; UCLA = UCLA Loneliness Scale; SCQ = Social Competence Questionnaire; CSI-SS/SW = Coping strategies inventory—social support/social withdrawal; ISEL = Interpersonal support evaluation list; DMQ-R = Drinking Motives Questionnaire—revised; IDS = Inventory of Drinking Situations; DRSE-ER = Drinking Refusal Self-Efficacy—emotional relief; SCQA = Situational Confidence Questionnaire—alcohol; MDMQ-R = Modified Drinking Motives Questionnaire; AEQ = Alcohol Expectancies Questionnaire. ^aThis paper contained two samples; all data referenced in this table come from sample 2. ^bThis was an adapted version of the DMQ-R using seven items for coping ('to forget my ongoing problems/worries', 'to feel less depressed', 'to feel less nervous', 'to avoid dealing with my ongoing problems', 'to cheer up', 'because I was angry' and 'to feel more confident/sure of myself'), two items for enhancement ('Because I like the pleasant feeling' and 'to have fun') and two items for social motives ('to make party/gathering more fun' and 'to improve party/gathering') on a three-point scale (0 = no, 1 = somewhat, 2 = definitely). ^cWechsler *et al.* 1994; Wechsler & Isaac, 1992; Wechsler & McFadden, 1979.

and young adults who endorsed drinking alone were more likely to be older relative to social-only drinkers [6,15,35,39]³ while others found no differences or suggested opposite findings [10,34,36]. Data on adolescent solitary drinking among different ethnicities/races were also inconsistent, despite using similar definitions/time-frames to assess solitary drinking [5,8,16,40–43]. We are unaware of studies investigating ethnic/racial differences in young adult solitary drinking. Evidence of sex differences among solitary drinkers was similarly equivocal. Some data suggested that males were more likely to drink alone as young adults [30,39,44,45] and adolescents [8,10,16,46], while others found no differences across sex [5,14,15,43,47]. Finally, regarding sexual orientation, three studies indicated that adolescents with same-sex attractions were more likely to drink alone [48–50].

Negative correlates of solitary drinking

For each correlate below, findings from the systematic review are presented first, followed by a summary of meta-analytical results.

Alcohol consumption and alcohol problems

Several cross-sectional studies found that adolescent and young adult solitary drinkers reported greater alcohol use than their social-only drinking peers [5,8–10,15,18,51],

and solitary drinking frequency was positively associated with alcohol use and problems in these individuals [52–54]. Further, solitary (versus social-only) young adult drinkers reported more alcohol-related problems [9], greater alcohol dependence severity [15], and less likelihood to change problem drinking [18], and adolescent solitary (versus social-only) drinkers reported more AUD symptoms [8]. Notably, in analyses controlling for alcohol use quantity/frequency, the association between solitary drinking (measured as both a continuous variable and a categorical yes/no variable) and alcohol problems held for both adolescents and young adults [5,8,53,54], suggesting that this association was not due to greater alcohol involvement but was specific to solitary drinking (although see [15] for null findings). Corroborating this, the meta-analytical results revealed significant small effect sizes for the relationships between solitary drinking and both increased 'alcohol consumption' and more 'drinking problems' (see Table 3).

Negative psychosocial outcomes

Beyond alcohol-related problems, adolescents and young adults who reported drinking alone earned poorer grades and missed more classes [5], were more likely to engage in risky behavior (e.g. unplanned sex⁴) and experienced more problems with authorities (i.e. getting arrested) than those who reported only drinking in social settings [18].

³Gonzalez & Skewes (2013) found age differences by gender, such that solitary heavy drinking men were significantly older than social heavy-drinking men.

⁴This is assumed to be a general association, not unplanned sex within a drinking event.

Table 2 Characteristics and quality assessments of reviewed articles.

Citation	Population	Design	Measure of solitary drinking	Rating
Anderson & Brown 2010	US population: middle school students (<i>n</i> = 1171)	Cross-sectional	Drinking context questions asking with whom and where on drinks	2 ^{b,c}
Armeli <i>et al.</i> 2014	US population: college students (<i>n</i> = 1421)	Cross-sectional	Number of drinks previous night 'alone/not interacting with others' versus 'with others/ in a social setting' over 30 days	1 ^b
Armeli <i>et al.</i> 2016 (sample 2)	US population: urban historically black US college/university (<i>n</i> = 452)	Cross-sectional	Number of drinks previous night 'alone/not interacting with others' versus 'with others/ in a social setting' over 30 days	0
Armeli <i>et al.</i> 2018	US population: college students (<i>n</i> = 927)	Cross-sectional	Number of drinks previous night 'alone/not interacting with others' versus 'with others/ in a social setting' over 30 days	2 ^{b,c}
Bailey & Rachal 1993	US population: middle and high school students (<i>n</i> = 2771)	Cross-sectional ^d	Drinking context questions asking with whom and where one drank in the past year	1 ^c
Beck, Ahmad & Farkas 2011	US population: Maryland motorists who had an alcohol-impaired driving citation (<i>n</i> = 161)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	1 ^c
Beck, Summons & Thombs 1991	US population: high school students (<i>n</i> = 1797)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Beck, Summons & Thombs 1993	US population: high school students (<i>n</i> = 1360)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Bilevicious <i>et al.</i> 2018	Canadian population: college students (<i>n</i> = 308)	Prospective longitudinal	Drinking context questions asking with whom and where one usually drinks	3 ^{a,b,c}
Blevins, Abrantes & Stephens 2018	US population: college students (<i>n</i> = 303)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Buckner & Terlecki 2016	US population: college students (<i>n</i> = 776)	Cross-sectional	Number of days on which drinking occurred in the past year in social (i.e. with others) and in solitary (i.e. alone) settings	1 ^b
Falcon <i>et al.</i> 2014	European population: Roma adolescents in three Spanish areas (<i>n</i> = 569)	Cross-sectional	Drinks alone often (not specified further)	0
Chalder, Elgar & Bennett 2006	European population: community sample of adolescents (<i>n</i> = 1744)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Christiansen, Vik & Jarchow 2002	US population: college students (<i>n</i> = 464)	Cross-sectional	Heavy drinking alone and/or being the only person drinking vs not in the previous 3 months	1 ^b
Cooper 1994	US population: community sample of adolescents (<i>n</i> = 1243)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Creswell <i>et al.</i> 2014	US population: clinical and community sample of adolescents (<i>n</i> = 709)	Prospective longitudinal	Life-time percentage of drinking spent without others present	2 ^{a,c}
Creswell <i>et al.</i> 2015	US population: clinical and community sample of adolescents (<i>n</i> = 761)	Cross-sectional	Life-time percentage of drinking spent without others present	1 ^c
Dauber <i>et al.</i> 2009	US population: black and white female middle school students (<i>n</i> = 2948)	Cross-sectional	High risk drinking context questions (e.g. drinking while drunk), including drinking alone	2 ^{b,c}
Degenhardt <i>et al.</i> 2015	Australian population: Victorian Adolescent Health cohort study (44 schools) (<i>n</i> = 1943)	Prospective longitudinal	Drinking contexts questions asking with whom and where one drinks	3 ^{a,b,c}
Gibbons <i>et al.</i> 1986	US population: rural middle and high school students (<i>n</i> = 650)	Cross-sectional	Drinking contexts questions asking with whom and where one usually drinks	1 ^c
Gonzalez, Collins & Bradizza 2009	US population: heavy drinking underage college students (<i>n</i> = 91)	Cross-sectional	Number of typical days drinking alone or while no one else was drinking versus not in a typical month	0
Gonzalez & Skewes 2013	US population: heavy drinking college students (<i>n</i> = 90)	Cross-sectional	Number of typical days drinking alone or while no one else was drinking versus not in a typical month	0

(Continues)

Table 2. (Continued)

Citation	Population	Design	Measure of solitary drinking	Rating
Gonzalez 2012	US population: heavy drinking college students ($n = 182$)	Cross-sectional	Number of typical days drinking alone or while no one else was drinking versus not in a typical month	0
Kablicek <i>et al.</i> 2018	European clinical population: adolescents from inpatient wards in the Czech Republic (30 wards) ($n = 1838$)	Cross-sectional	Drinking contexts questions asking with whom one drank at time of admission	1 ^c
Kask & Markina 2014	European population: adolescents from 25 European countries ($n = 57\,771$)	Cross-sectional	Drinking contexts question asking with whom one drank on last drinking occasion	2 ^{b,c}
Keough <i>et al.</i> 2015	US population: college students ($n = 295$)	Cross-sectional	Drinking contexts question asking with whom one usually drank in the past 6 months	2 ^{b,c}
Keough <i>et al.</i> 2016	US population: college students ($n = 293$)	Cross-sectional	Drinking contexts question asking with whom one usually drank in the past 6 months	2 ^{b,c}
Keough <i>et al.</i> 2018	US population: college students ($n = 118$)	Cross-sectional	Drinking contexts question asking with whom one usually drank in the past 6 months	2 ^{b,c}
Koposov <i>et al.</i> 2002	Russian population: adolescents from 25 secondary schools ($n = 387$)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Kouzis & Labouvie 1992	US population: community sample of adolescents ($n = 437$)	Prospective longitudinal	Drinking context questions asking with whom and where one usually drinks	3 ^{a,b,c}
Lowman 1981	US population: national probability survey of 10–12th graders ($n =$ not specified)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Mayer <i>et al.</i> 1998	US population: 9th and 12th graders ($n = 4646$)	Cross-sectional	Drinking context questions asking with whom and where one drank on last drinking occasion	1 ^b
McCabe <i>et al.</i> 2014	US population: High school seniors ($N = 24\,809$)	Cross-sectional	Drinking context questions asking with whom and where one drinks	2 ^{b,c}
McGee <i>et al.</i> 2011	US population: high school students ($n = 6748$)	Cross-sectional	Drinking context questions asking with whom and where one drinks	1 ^c
O'Hara <i>et al.</i> 2015	US population: urban historically black US college/university ($n = 452$)	Cross-sectional	Number of drinks previous night 'alone/not interacting with others' versus 'with others/ in a social setting' over 30 days	0
O'Hara <i>et al.</i> 2014	US population: urban historically black US college/university ($n = 462$)	Cross-sectional	Number of drinks previous night 'alone/not interacting with others' versus 'with others/ in a social setting' over 30 days	0
O'Hara, Armeli, & Tennen, 2015	US population: college students ($n = 722$)	Cross-sectional	Number of drinks previous night 'alone/not interacting with others' versus 'with others/ in a social setting' over 30 days	1 ^b
O'Hare, 1990	US population: college students	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Okulicz-Kozaryn & Borucka 2013	European population: 15-year-old Polish students ($n = 1229$ – 3918)	Longitudinal	Drinking context question asking with whom one drank on the last drinking occasion	1 ^b
Pederson, LaBrie, & Kilmer, 2009	US population: college students ($n = 444$)	Cross-sectional	Drinking context questions asking with whom one usually pre-parties	1 ^b
Rivers & Noret 2008	European population: adolescents from 14 schools in England ($n = 106$)	Cross-sectional	Drinking context question asking how often one drank alone	1 ^b
Russell <i>et al.</i> 2002	US population: middle and high school students	Prospective longitudinal	Single item on ever being drunk while alone	2 ^{a,b}
Skrzynski <i>et al.</i> 2018	US population: underage drinkers aged 18–20 years ($n = 664$)	Cross-sectional	Life-time percentage of drinking spent without others present	2 ^{b,c}
Stewart & Power 2003	US population: high school students ($n = 1874$)	Cross-sectional	Drinking context questions asking with whom and where one drinks	1 ^b

(Continues)

Table 2. (Continued)

Citation	Population	Design	Measure of solitary drinking	Rating
Strunin & Demissie 2001	US population: middle school students ($n = 314$)	Cross-sectional	Item asking if participants ever drank alcohol alone	
Swahn & Donovan 2004	US population: nationally representative sample of adolescents from middle and high school ($n = 8885$)	Prospective longitudinal	Drinking context question asking if one ever drank alcohol alone	2 ^{a,b}
Swahn <i>et al.</i> 2004	US population: nationally representative sample of adolescents from middle and high school ($n = 8885$)	Cross-sectional	Drinking context question asking if one ever drank alcohol alone	1 ^b
Swahn & Donovan 2005	US population: nationally representative sample of adolescents from middle and high school ($n = 6041$)	Prospective longitudinal	Drinking context question asking if one ever drank alcohol alone	2 ^{a,b}
Swahn & Donovan 2006	US population: nationally representative sample of adolescents from middle and high school ($n = 8866$)	Cross-sectional	Drinking context question asking if one ever drank alcohol alone	1 ^b
Terry-McElrath <i>et al.</i> 2017	US population: nationally representative sample of high school seniors ($n = 16\,902$)	Cross-sectional	Drinking context questions asking with whom one often drinks	2 ^{b,c}
Thombs <i>et al.</i> 1994	US population: high school students ($n = 1484$)	Cross-sectional	Drinking context questions asking with whom and where one usually drinks	2 ^{b,c}
Tomlinson & Brown 2012	US population: 8th grade students ($n = 406$)	Cross-sectional	Drinking context questions with whom and how often one drank in the past month	2 ^{b,c}
Tucker <i>et al.</i> 2006	US population: 8th grade students and later, same students at age 23 [$n = 2003$ (drinkers)]	Prospective longitudinal	Item asking if participants ever drank alone in their life-time	2 ^{a,b}
Tucker <i>et al.</i> 2008	US population: 6th and 7th grade students and later, same students at age 23 ($n = 1633$)	Prospective longitudinal	Item asking if participants ever drank alone in their life-time	2 ^{a,b}
Tucker <i>et al.</i> 2014	US population: 6th and 7th grade students ($n = 818$)	Cross-sectional	Item asking if participants ever drank alone in their life-time	1 ^b
Williams, Vik & Wong 2015	US population: college students ($n = 134$)	Cross-sectional	Heavy drinking alone and/or being the only person drinking versus not in the previous 3 months	1 ^b
West <i>et al.</i> 1990	European population: college students ($n = 270$)	Cross-sectional	Drinking context question asking if one drank alone (not further specified)	1 ^b

^aProspective longitudinal design; ^brepresentative sample; ^cstandardized measure of solitary use. ^dThis study was a longitudinal design overall, but data from the third wave was used for an exploratory factor analysis including an item on drinking alone.

Further, being an adolescent or young adult solitary drinker was associated with violence and deviant acts (e.g. assault) [45,55–57], even after controlling for drinking frequency and binge drinking [55].

Negative affectivity

Solitary drinking in adolescents and young adults was also associated with NA. Adolescent solitary drinkers reported more NA than adolescent social-only drinkers [8], and young adult heavy solitary drinkers reported more depressive symptoms than their social-only drinking counterparts [9,15,18]. Additionally, solitary drinking frequency was positively associated with depressive symptoms among both adolescents and young adults [14,53], and quantity of alcohol consumed in solitary settings was related to suicidal ideation and attempts

[27] and NA among young adults [58]. These associations may be bi-directional, given that NA has been shown to predict later solitary drinking in longitudinal research [54], and laboratory findings show that drinking in a solitary context increases NA [59–61]. Meta-analytical results revealed a small effect size between solitary drinking and 'negative affect' (see Table 3).

Social discomfort

Finally, adolescent and young adult solitary drinking was associated with social discomfort. For instance, among young adults, solitary drinking frequency and the percentage of drinking episodes that occurred while alone were both positively associated with social anxiety [7,32,62]. Solitary drinking percentage was also positively associated

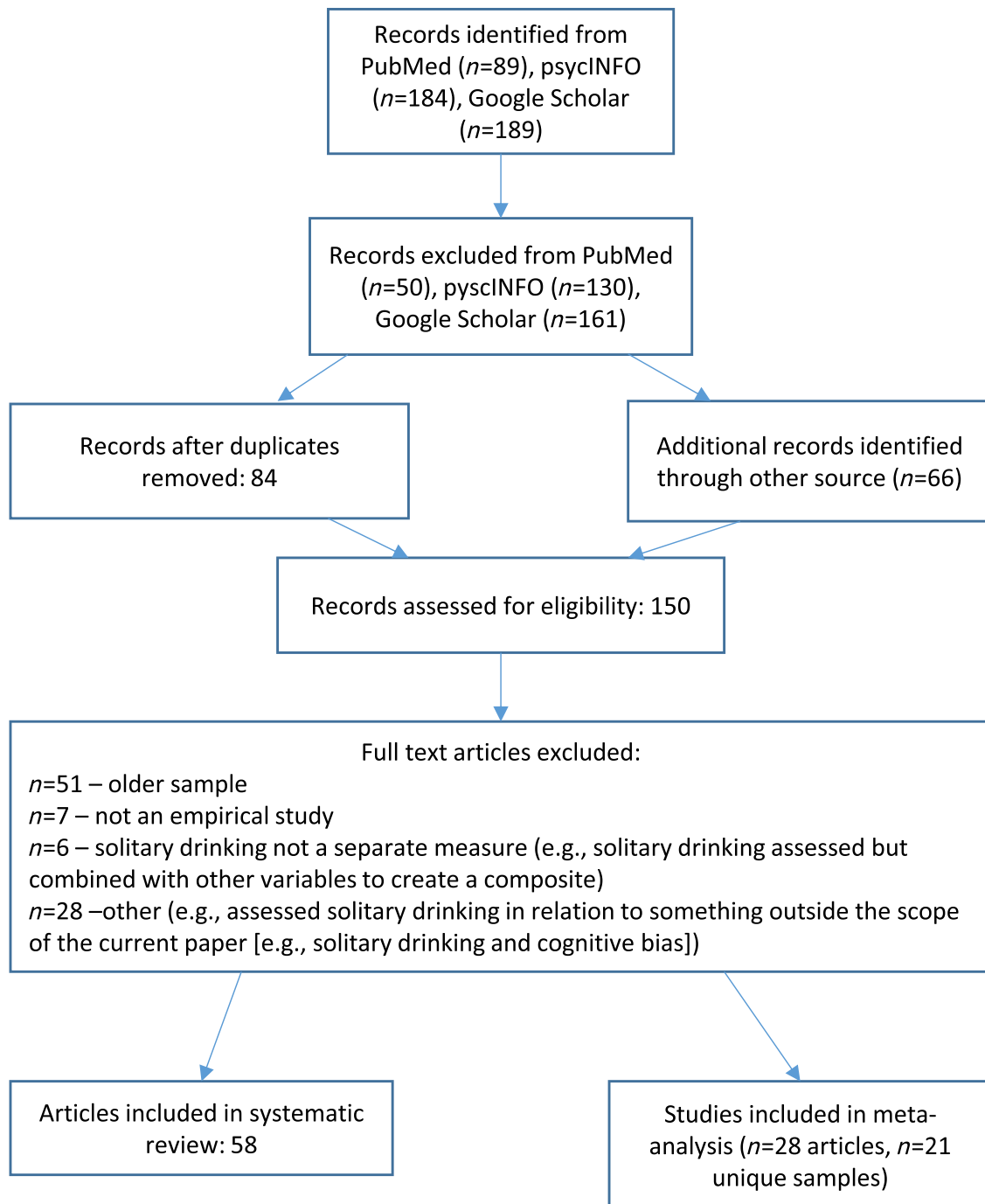


Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram for papers selected for the systematic review and meta-analysis. [Colour figure can be viewed at wileyonlinelibrary.com]

with loneliness and negatively associated with perceived social support in young adults [7]. Additionally, young adult heavy solitary drinkers reported lower perceived social competence than social-only heavy drinkers [15], and adolescent solitary drinkers reported less time participating in school or other organized activities than social-only drinkers [5]. Mixed findings have been reported, however.

Some researchers have found no differences between heavy solitary and social-only college drinkers on their social network size or their drinking network satisfaction [15]. Similarly, others have found that adolescent solitary drinking status (yes/no), as well as the quantity of alcohol adolescents consume while alone, were associated with spending more time on social activities (e.g. hanging out with friends)

Table 3 Meta-analysis of superordinate factors and underlying variables of interest and solitary drinking.

Study authors	Superordinate factor	n	r	95% CI	P	Heterogeneity	
						Q	P
Alcohol consumption							
Anderson & Brown 2010		1160	0.66	0.63, 0.70	< 0.001		
Armeli <i>et al.</i> 2016 ^a		452	0.07	-0.03, 0.16	0.16		
Armeli <i>et al.</i> 2018 ^b		927	0.29	0.23, 0.35	< 0.001		
Blevins, Abrantes & Stephens 2018		301	0.00	-0.11, 0.11	0.99		
Buckner & Terlecki 2016		776	0.26	0.19, 0.32	< 0.001		
Christiansen, Vik & Jarchow 2002 ^c		262	0.17	0.05, 0.28	< 0.01		
Creswell <i>et al.</i> 2014 ^d		761	0.26	0.19, 0.32	< 0.001		
Creswell <i>et al.</i> 2015 ^d							
Gonzalez, Collins & Bradizza 2009		91	0.36	0.17, 0.53	< 0.001		
Falcón <i>et al.</i> 2014		566	0.17	-0.04, 0.37	0.12		
Keough <i>et al.</i> 2015 ^e		295	0.02	-0.09, 0.13	0.73		
Keough <i>et al.</i> 2016 ^e		293					
O'Hara, Armeli & Tennen 2015 ^b		722					
O'Hara <i>et al.</i> 2014 ^a		462					
O'Hara <i>et al.</i> 2015 ^a		452					
Skrzynski <i>et al.</i> 2018		664	0.16	0.08, 0.23	< 0.001		
Stewart & Powers 2003		1227	0.20	0.15, 0.26	< 0.001		
Terry-McElrath, Stern & Patrick 2017		16 902	0.04	-0.02, 0.10	0.17		
Tucker <i>et al.</i> 2006 ^c		1996	0.41	0.38, 0.45	< 0.001		
Tucker <i>et al.</i> 2014		818	0.28	0.22, 0.34	< 0.001		
Williams, Vik & Wong 2015		134	0.14	-0.03, 0.30	0.09		
Overall estimate			0.23	0.12, 0.33	< 0.001	522.43	< 0.001
Drinking problems							
Anderson & Brown 2010		1118	0.59	0.56, 0.63	< 0.001		
Armeli <i>et al.</i> 2018		927	0.13	0.07, 0.19	< 0.001		
Beck, Ahmad & Farkas 2011		73	0.22	-0.01, -0.43	0.06		
Bilevicious <i>et al.</i> 2018		308	0.09	-0.03, 0.20	0.14		
Buckner & Terlecki 2016		776	0.17	0.10, 0.23	< 0.001		
Christiansen, Vik & Jarchow 2002		262	0.24	0.13, 0.35	< 0.001		
Creswell <i>et al.</i> 2015		535	0.16	0.07, 0.24	< 0.001		
Gonzalez, Collins & Bradizza 2009		91	0.26	0.06, 0.44	< 0.05		
Gonzalez & Skewes 2013		90	0.42	0.23, 0.58	< 0.001		
Keough <i>et al.</i> 2015 ^e		295	0.09	-0.02, 0.20	0.12		
Keough <i>et al.</i> 2016 ^e		293					
Keough <i>et al.</i> 2018		118	0.14	-0.04, 0.32	0.12		
Skrzynski <i>et al.</i> 2018		664	0.26	0.19, 0.33	< 0.001		
Stewart & Powers 2003		1227	0.25	0.19, 0.30	< 0.001		
Tucker <i>et al.</i> 2014		818	0.28	0.22, 0.34	< 0.001		
West, Drummond & Eames 1990		270	0.14	0.02, 0.25	0.02		
Williams, Vik & Wong 2015		134	0.12	-0.05, 0.29	0.16		
Overall estimate			0.23	0.13, 0.32	< 0.001	256.36	< 0.001
Negative affect							
Anderson & Brown 2010		1159	0.26	0.20, 0.31	< 0.001		
Armeli <i>et al.</i> 2016 ^a		451	0.22	0.13, 0.31	< 0.001		
Armeli <i>et al.</i> 2018		927	0.16	0.09, 0.22	< 0.001		
Bilevicious <i>et al.</i> 2018		308	0.13	0.01, 0.23	< 0.05		
Christiansen, Vik & Jarchow 2002		262	0.30	0.19, 0.40	< 0.001		
Creswell <i>et al.</i> 2015		709	0.12	0.05, 0.19	< 0.01		
Gonzalez 2012 ^f		182	0.26	0.07, 0.43	< 0.005		
Gonzalez & Skewes 2013 ^f		90					
Gonzalez, Collins & Bradizza 2009		91	0.20	-0.01, 0.39	0.06		
Keough <i>et al.</i> 2015		295	0.31	0.20, 0.41	< 0.001		
O'Hara <i>et al.</i> 2015 ^a		452					

(Continues)

Table 3. (Continued)

Study authors	Superordinate factor	n	r	95% CI	P	Heterogeneity	
						Q	P
Overall estimate			0.21	0.16, 0.26	< 0.001	220.17	< 0.05
	Social discomfort						
Buckner & Terlecki 2016		776	0.06	-0.01, 0.13	0.08		
Gonzalez & Skewes 2013		90	0.16	-0.05, 0.36	0.13		
Keough <i>et al.</i> 2016		293	0.31	0.20, 0.41	< 0.001		
Skrzynski <i>et al.</i> 2018		664	0.15	0.08, 0.23	< 0.001		
Overall estimate			0.17	0.06, 0.27	< 0.001	14.22	0.01
	Negative reinforcement						
Armeli <i>et al.</i> 2016 ^a		451	0.35	0.27, 0.43	< 0.001		
Armeli <i>et al.</i> 2018 ^b		927	0.18	0.12, 0.24	< 0.001		
Beck, Ahmad & Farkas 2011		162	0.26	0.11, 0.40	< 0.001		
Blevins Abrantes & Stephens 2018		301	0.29	0.18, 0.39	< 0.001		
Christiansen, Vik & Jarchow 2002		262	0.20	0.09, 0.32	< 0.001		
Creswell <i>et al.</i> 2014 ^c		698	0.24	0.17, 0.31	< 0.001		
Creswell <i>et al.</i> 2015 ^c		709					
Gonzalez & Skewes 2013		90	0.46	0.28, 0.61	< 0.001		
Gonzalez, Collins & Bradizza 2009		91	0.27	0.07, 0.45	0.01		
O'Hara <i>et al.</i> 2014 ^a		462					
O'Hara, Armeli & Tennen 2015 ^b		722					
Skrzynski <i>et al.</i> 2018		664	0.31	0.24, 0.38	< 0.001		
Stewart & Powers 2010		1227	0.34	0.29, 0.39	< 0.001		
Terry-McElrath, Stern & Patrick 2017		16 902	0.29	0.28, 0.31	< 0.001		
Tucker <i>et al.</i> 2014		818	0.24	0.17, 0.30	< 0.001		
Williams, Vik & Wong 2015		134	0.19	0.02, 0.35	< 0.05		
Overall estimate			0.28	0.24, 0.31	< 0.001	30.64	< 0.005
	Positive reinforcement						
Armeli <i>et al.</i> 2016 ^a		452	-0.03	-0.12, 0.06	0.54		
Armeli <i>et al.</i> 2018 ^b		927	-0.05	-0.11, 0.01	0.13		
Beck, Ahmad & Farkas 2011		162	0.07	-0.08, 0.22	0.37		
Blevins, Abrantes & Stephens 2018		303	-0.03	-0.14, 0.09	0.63		
Christiansen, Vik & Jarchow 2002		262	0.24	0.13, 0.35	< 0.001		
Creswell <i>et al.</i> 2014		698	0.19	0.12, 0.26	< 0.001		
Gonzalez, Collins & Bradizza 2009		91	0.10	-0.11, 0.30	0.37		
O'Hara <i>et al.</i> 2014 ^a		462					
O'Hara, Armeli & Tennen 2015 ^b		722					
Stewart & Powers 2003		1227	0.22	0.16, 0.27	< 0.001		
Terry-McElrath, Stern & Patrick 2017		16 902	0.06	0.04, 0.07	< 0.001		
Tucker <i>et al.</i> 2014		818	0.21	0.14, 0.27	< 0.001		
Overall estimate			0.10	0.03, 0.17	< 0.001	86.56	< 0.001

For studies with multiple variables of interest per superordinate factor, these variables are combined and generate an overall *r*, 95% confidence interval (CI), and *P*-value. When the relationships between variables of interest and solitary drinking were negatively correlated but still in the direction of the superordinate factor, the effect directions were coded positively so that effects aligned (e.g. solitary drinking was negatively correlated with perceived social support, but this relationship was coded so it contributed a positive value to the 'social discomfort' factor given that this signifies greater social problems).^{a,b,d,e,f} These studies used the same sample and thus the statistics were averaged over them to avoid problems from contributing multiple weights to the same superordinate factor.^g These sample sizes include only alcohol drinkers in the case of Tucker *et al.* 2006 (the whole sample size was 3303, which included students who used other substances) and only heavy social-only and heavy solitary drinkers in the case of Christiansen, Vik & Jarchow 2002 (the whole sample size was 325, which included students who were non-heavy drinkers).

[5,46]. To reconcile this, some have speculated that solitary drinkers, while being socially active, may not be as comfortable in social settings as social-only drinkers [7,15]. Consistent with this hypothesis, our meta-analytical results revealed a small effect size between solitary drinking and 'social discomfort' (see Table 3).

Consequences of solitary drinking

We are aware of six longitudinal studies among adolescents and young adults that tested whether solitary drinking prospectively predicts alcohol problems and other negative outcomes after controlling for baseline risk factors

[5,8,30,54,56,63,64].⁵ Findings generally corroborated cross-sectional links between solitary drinking and negative outcomes. For instance, solitary drinkers in eighth grade went on to have more physical health problems, deviant behavior, and academic problems at age 23 than their social-only drinking peers [5]. Solitary drinking in adolescence (aged 12–18), measured as a percentage of total drinking episodes, also predicted age 25 AUD symptoms among both clinical and community samples [8]. Additionally, among university students, frequency of solitary drinking at the beginning of first semester predicted increased harmful drinking at the end of first semester, and solitary drinking mediated the link between increased NA and harmful drinking [54]. Finally, adolescent solitary drinkers had a higher incidence of risky drinking in later adolescence compared to social-only drinkers [63]. Of note, these findings held even after controlling for baseline alcohol use/problems [5,8,54] and other risk factors (e.g. NA, other drug use) [63], suggesting that solitary drinking accounts for unique variance in alcohol use and problems and may be an early warning sign for the development of AUD.

In two studies, solitary drinking failed to predict later psychosocial problems, but this may be because it was entered into regression models that included several other predictor variables. Specifically, Swahn & Donovan [56,64] found that adolescent solitary drinking (yes/no) was not a longitudinal predictor of violent behavior when it was entered into a regression model with demographic variables and nine other drinking variables (e.g. drinking quantity/frequency, unsupervised drinking, receiving drug and alcohol abuse treatment). Armeli and colleagues [30] found a significant, positive correlation between quantity of drinks consumed in solitary settings and drinking problems 5 years later in young adults, but drinking alone was no longer significant when entered into a regression model that included several other predictors (e.g. adult social roles, physical ailment symptoms, NA).

Reasons for solitary drinking

To our knowledge, no studies have assessed drinking motives specifically for solitary alcohol use. In other words, all of the studies reviewed below examined associations between drinking motives (with no context specified) and drinking that is social versus solitary (or differences across solitary versus social-only drinkers).

Negative reinforcement

Many studies have linked drinking to cope motives with adolescent and young adult solitary drinking (measured as both a continuous variable and a categorical yes/no

variable) [6,7,9,15,28,30,31,65,66]. Importantly, the association between solitary drinking quantity/frequency and drinking to cope motives held even after controlling for social, enhancement, and conformity motives [9,11,31,66]. Further, young adult solitary drinkers reported greater beliefs in alcohol's ability to reduce NA than social-only drinkers [18], and being a solitary drinker was associated with drinking in the context of NA but not PA in adolescents [8]. Additionally, the perceived inability to refuse alcohol during NA completely mediated the relationship between NA and solitary drinking status (yes/no) in a large sample of adolescents [10]. This is consistent with prior research [18] showing that college student heavy solitary drinkers had less confidence in their ability to resist drinking during NA than their social-only drinking peers. Finally, several studies have found that solitary drinking frequency loaded onto factors that include drinking to cope items (e.g. to get rid of depression) in adolescents and young adults [67–71]. Notably, our meta-analysis revealed a significant small-to-medium effect size between solitary drinking and 'negative reinforcement' (see Table 3).

Positive reinforcement

While most research supports an association between negative reinforcement processes and solitary drinking in adolescents and young adults, some studies suggest that positive reinforcement (e.g. drinking to enhance PA) may also be associated with drinking alone. Specifically, in four studies, solitary drinking was related to both positive and negative reinforcement [18,41,42,51]. However, in two of the four studies, alcohol expectancies were assessed, which are thought to be more distal to drinking behavior than drinking motives. Individuals may hold certain expectancies about drinking but still not drink, while motivations are thought to be necessary for drinking to occur [4,11–13]. Indeed, several studies showed that social and enhancement motives were either unrelated to drinking alone [9,30,65] or negatively associated with it [11,31]. Furthermore, solitary drinking was not related to drinking during PA [8]. While the meta-analytical results between solitary drinking and the 'positive reinforcement' factor were significant, the effect size was nearly three times smaller than that of the 'negative reinforcement' factor (see Table 3).

Heterogeneity in effect sizes and moderator variables

As shown in Table 3, the *Q* values for heterogeneity, which represent variation in the true effect size across studies,

⁵Swahn & Donovan 2006 [56] and Swahn & Donovan 2005 [64] used the same sample.

were significant for all factors. Table 4 shows results for moderator analyses. As can be seen, none of the moderators (i.e. age group, study quality, and differing solitary drinking definitions) were significant.

Publication bias

Although Begg's rank correlation test resulted in null findings, there was evidence of publication bias for the factors of 'alcohol consumption', 'drinking problems', 'social discomfort', and 'positive reinforcement' based on visual inspection of funnel plots and trim-and-fill analyses. These analyses suggested the possibility of six unpublished studies for 'alcohol consumption' and 'drinking problems', and two unpublished studies for 'social discomfort' and 'positive reinforcement'. Imputation of these studies increased the effect sizes from $r = 0.23$ to 0.34 for 'alcohol consumption' and from $r = 0.23$ to $r = 0.30$ for 'drinking problems', and lowered it from $r = 0.10$ to 0.06 for 'positive reinforcement'

and from $r = 0.17$ to 0.11 for 'social discomfort' (see Supporting information).

DISCUSSION

The current study provides results of a systematic review along with findings from the first meta-analysis to evaluate the strength and reliability of presumed solitary drinking effects. Findings demonstrated that solitary drinking is a reliable indicator of increased risk for AUD in adolescents and young adults. Correlational studies showed that it is associated with increased alcohol use and problems, as well as issues in academic, legal, interpersonal, emotional, and physical health domains (e.g. [5,7,8,18]). Importantly, longitudinal studies showed that solitary drinking predicts future alcohol problems after controlling for baseline risk factors (e.g. alcohol consumption/problems) [5,8,54,63]. Meta-analytical results showed small but significant effect sizes between

Table 4 Moderation analyses.

	Moderator	<i>n</i>	Point estimate	Confidence interval	<i>Q</i>	<i>P</i>
<i>Superordinate factor</i>	<i>Definition</i>					
Alcohol consumption	Alone	10	0.24	0.08, 0.38	0.08	0.77
	All others	6	0.21	0.13, 0.29		
Drinking problems	Alone	10	0.23	0.10, 0.36	0.24	0.62
	All others	6	0.20	0.13, 0.26		
Negative affect	Alone	4	0.20	0.11, 0.29	0.03	0.87
	All others	5	0.21	0.15, 0.27		
Social discomfort	Alone	2	0.23	0.07, 0.38	3.07	0.08
	All others	2	0.07	0.01, 0.14		
Negative reinforcement	Alone	7	0.29	0.26, 0.31	0.24	0.62
	All others	6	0.27	0.18, 0.35		
Positive reinforcement	Alone	6	0.13	0.04, 0.21	0.72	0.40
	All others	4	0.06	-0.08, 0.19		
Alcohol consumption	Age group ^a					
	Adolescents	7	0.31	0.12, 0.47	2.14	0.14
Young adults	9	0.16	0.08, 0.24			
Drinking problems	Adolescents	4	0.33	0.11, 0.53	1.85	0.17
	Young adults	12	0.18	0.13, 0.22		
Negative affect	Adolescents	2	0.19	0.06, 0.32	0.14	0.71
	Young adults	7	0.22	0.16, 0.27		
Negative reinforcement	Adolescents	4	0.29	0.25, 0.32	0.13	0.72
	Young adults	9	0.27	0.22, 0.33		
Positive reinforcement	Adolescents	4	0.17	0.06, 0.27	3.07	0.08
	Young adults	6	0.04	-0.05, 0.14		
	Quality level ^b				Z-value	
Alcohol consumption		16	0.03	-0.12 to 0.18	0.40	0.69
Drinking problems		16	-0.04	-0.17 to 0.10	-0.52	0.60
Negative affect		9	-0.01	-0.07 to 0.04	-0.45	0.65
Social discomfort		4	0.06	-0.06 to 0.18	0.80	0.42
Negative reinforcement		13	-0.04	-0.09 to 0.01	-1.43	0.15
Positive reinforcement		10	-0.02	-0.12 to 0.08	-0.41	0.69

^aSocial discomfort only contained young adult samples, and thus was not included in these analyses. ^bQuality level analyses were run using meta-regression with quality level designated as a continuous variable.

solitary drinking and increased alcohol consumption, drinking problems, NA, and social discomfort. Notably, after accounting for publication bias, there were medium effect sizes between solitary drinking and increased alcohol consumption and drinking problems. The strengths of all relationships varied significantly across studies for all factors, but this heterogeneity was not explained by age group, suggesting that solitary drinking is problematic in both adolescents and young adults. The heterogeneity across studies was also not explained by differing solitary drinking definitions or study quality. Future studies are indicated to further explore this heterogeneity.

Understanding why individuals drink alone is essential for developing effective interventions. Results suggested that the most compelling theory to date is a motivational model in which adolescents and young adults drink alone to cope with NA. Solitary drinking in these individuals has been linked to coping motives over and above other drinking motives (i.e. social, enhancement, and conformity motives), beliefs in alcohol's ability to mitigate NA, the inability to resist drinking during NA, and problems coping with discomfort or regulating emotions (e.g. [6,8,9,11]). Indeed, our meta-analytical results revealed a small-to-medium effect size for studies examining these relationships. Further, adolescent and young adult solitary drinkers reported more NA and NA-inducing experiences (e.g. social discomfort) than social-only drinkers (e.g. [8,15]), perhaps making it more likely for them to use alcohol to cope with NA. There is research to support this: a recent longitudinal study demonstrated that NA (e.g. depression) prospectively predicted solitary drinking in young adults, even after accounting for baseline solitary drinking [54]. While all studies to date are correlational, taken together these results suggest that negative reinforcement processes may be a primary mechanism driving solitary drinking among both adolescents and young adults.

Conversely, positive reinforcement was not as strongly related to solitary drinking. Most studies showed that enhancement and social motives were unrelated [9,30,65] or negatively associated with drinking alone [11,31], and two of the four studies that found a positive relationship assessed alcohol expectancies [18,41], which are more distally related to drinking than motives [12,13]. While the meta-analytical results indicated a significant relationship between solitary drinking and the 'positive reinforcement' factor, the effect size was nearly three times smaller than that of the 'negative reinforcement' factor. Experimental data are needed, but the existing correlational data converge to support drinking to cope motives as a likely predictive and contributing factor for solitary drinking while positive reinforcement is a weaker motive.

In summary, while solitary drinking is less common than social drinking, it has substantial negative implications for adolescents and young adults who engage in it.

The most compelling theory for why individuals drink alone is that they are doing so to cope with NA. However, a limitation of this review and the literature more generally on solitary drinking is that nearly all studies use correlational designs. More rigorous tests are needed to understand the mechanisms underlying solitary drinking and the pathways by which drinking alone leads to adverse outcomes. For instance, analysis of longitudinal repeated-measures data would permit the study of dynamic changes in the sequence of events leading to solitary drinking and from solitary drinking to negative outcomes. These study designs, although still correlational, can provide stronger information about the causal processes operating in the day-to-day lives of young drinkers by demonstrating temporal precedence. They would be particularly helpful with adolescent populations, as it is not possible to conduct alcohol administration studies with underage drinkers. Experimental designs using vignettes or alcohol administration protocols could be conducted with young adults to test the hypothesized motivational model of solitary alcohol consumption. For example, mood manipulations could be used to induce NA to determine whether it increases the preference to drink alone among individuals with a history of solitary drinking. We are currently conducting such a study (<https://osf.io/e7yxn/register/5771ca429ad5a1020de2872e>) to test for a causal relationship between NA, drinking to cope motives, and solitary drinking among young adults. In general, intensive longitudinal designs and experimental protocols will aid in our understanding of the factors that evoke solitary drinking and help establish the necessary directional and causal relationships between negative reinforcement and drinking alone.

It is interesting to note that while drinking to cope seems to be the primary motivation for solitary drinking among adolescents and young adults, drinking alone may not be effective in ameliorating NA. For instance, in laboratory studies, young adults reported increased NA and decreased PA in solitary versus social drinking contexts [59–61,72–74]. It will be important to replicate these laboratory findings in samples that include only solitary drinkers, however, as drinking alone in these laboratory studies might be an aversive experience for social-only drinkers. It is noteworthy that solitary drinking dampened the pleasurable effects of alcohol in ecological momentary assessment (EMA) studies among individuals who chose to drink alone [75,76]. If future studies corroborate this, the findings could have important treatment implications. For instance, it might be helpful to challenge adolescents' and young adults' beliefs about the effectiveness of solitary drinking in ameliorating NA by describing studies that have examined in-the-moment affective consequences of drinking alone, and provide instruction on more effective ways to cope with NA.

Some other considerations also may improve future research. First, standardizing the definition of solitary drinking as drinking while alone would create a more consistent measure for establishing associations between solitary drinking and other variables. Second, more research is needed to replicate initial findings showing that early solitary drinking predicts increased alcohol involvement and the development of alcohol problems over time beyond the influence of other related risk factors. Third, to our knowledge, no studies have assessed drinking motives specifically for solitary alcohol use but rather have examined associations between solitary drinking and drinking motives with no context specified. Future studies are indicated that explicitly ask about solitary drinking motives. Fourth, while problems associated with solitary drinking are well established, other areas, such as associated demographic variables, remain under-investigated or equivocal. Studies investigating demographic variables and other individual differences linked to solitary drinking are indicated, so that intervention programs can be focused on those who need it most. Finally, solitary use of other drugs has also been linked to negative outcomes (e.g. [5,77]), and future studies should continue to explore the role of negative reinforcement in this drug use behavior. In general, more research is needed to fully understand the mechanisms driving solitary drinking and who may be most at risk to engage in this risky drinking pattern. Such research will shed light on a minority of adolescents and young adults who appear to be especially vulnerable to heavy drinking and the development of alcohol problems.

Declaration of interests

None.

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Author Contributions

Carillon J. Skrzynski: Investigation; methodology. **Kasey G. Creswell:** Conceptualization; funding acquisition; investigation; methodology; supervision.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 PRISMA checklist

Figure S1 Example of a full electronic search method

Figure S2 Funnel plots of superordinate factors including imputed studies

Table S1 Duvall and Tweedie's Trim-and-fill analyses

Table S2 Begg's Rank correlation test