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Concurrent validity of the Alcohol Purchase Task for measuring the reinforcing efficacy of alcohol: an updated systematic review and meta-analysis

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Abstract

Background and aims—An early meta-analysis testing the concurrent validity of the Alcohol Purchase Task (APT), a measure of alcohol's relative reinforcing value, reported mixed associations, but predated a large number of studies. This systematic review and meta-analysis sought to: (1) estimate the relationships between trait-based alcohol demand indices from the APT and multiple alcohol indicators, (2) test several moderators and (3) analyze small study effects.

Methods—A meta-analysis of 50 cross-sectional studies in four databases (n = 18 466, females = 43.32%). Sex, year of publication, number of APT prices and index transformations (logarithmic, square root or none) were considered as moderators. Small study effects were examined by using the Begg-Mazumdar, Egger's and Duval & Tweedie's trim-and-fill tests. Alcohol indicators were quantity of alcohol use, number of heavy drinking episodes, alcohol-related problems and hazardous drinking. APT indices were intensity (i.e. consumption at zero cost), elasticity (i.e. sensitivity to increases in costs), O_{max} (i.e. maximum expenditure), P_{max} (i.e. price associated to O_{max}) and breakpoint (i.e. price at which consumption ceases).

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Declaration of interests

J.M. is a principal in a private company, BEAM Diagnostics, Inc., but no commercial products fall within the scope of the review. No other authors have any declarations to disclose.

Supporting Information

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

Results—All alcohol demand indices were significantly associated with all alcohol-related outcomes (r = 0.132–0.494), except P_{max}, which was significantly associated with alcohol-related problems only (r = 0.064). The greatest associations were evinced between intensity in relation to alcohol use, hazardous drinking and heavy drinking and between O_{max} and alcohol use. All the tested moderators emerged as significant moderators. Evidence of small-study effects was limited.

Conclusions—The Alcohol Purchase Task appears to have concurrent validity in alcohol research. Intensity and O_{max} are the most relevant indices to account for alcohol involvement.

Keywords

Alcohol; alcohol purchase task; behavioral economics; concurrent validity; hazardous drinking; meta-analysis

INTRODUCTION

Alcohol misuse is a major contributor to morbidity and mortality world-wide. Drinking accounts for one-third of deaths due to cardiovascular diseases, and diabetes and is a risk factor for different cancers [1]. The associated costs of alcohol use is estimated at $249 billion in the United States [2] and at 1–3.5% gross domestic product (GDP) in several European Union countries [3]. The analysis of conditions under which individuals engage in excessive drinking at the expense of other potentially available reinforcers has been extensively examined using behavioral economics (BE), a hybrid field integrating behavioral psychology and micro-economics [4]. Specifically, BE defines alcohol use fundamentally as an operant behavior and, consequently, the study of the reinforcing efficacy of alcohol, in general and over other reinforcers, constitutes a priority area in the field [5].

The analysis of reinforcing efficacy of drugs has shifted from progressive-ratio schedules in self-administration studies to estimated consumption via hypothetical purchases [6,7]. This latter option allows to assess drug-reinforcing value under different constraints (e.g. typical drinking situation versus acute states; availability of a single drug versus two or more) while reducing resource demand, participant burden and ethical concerns. In the alcohol field, the Alcohol Purchase Task (APT) provides a behavioral economic proxy of alcohol use valuation [8]. In addition to its sound psychometric properties [9], hypothetical APTs provide data that converge with actual APTs [10,11] while reducing burden and eliminating ethical concerns, especially when assessing individuals with alcohol-related problems.

More specifically, the APT offers five demand indices capturing different aspects of the alcohol-reinforcing efficacy: intensity of demand (i.e. consumption at zero cost), elasticity of demand (i.e. sensitivity to increases in costs), O_{max} (i.e. maximum expenditure), P_{max} (i.e. price associated to O_{max}) and breakpoint (i.e. price that suppresses consumption). Collectively, these five indices provide a comprehensive perspective on alcohol valuation and offer clinical and experimental insights. For example, heavy-drinking smokers show increased alcohol O_{max} and breakpoint [12], and adulterated alcohol solutions administered under devaluation paradigms specifically reduce alcohol choice via intensity decreases [13].

Fostered by the widespread use of hypothetical purchase tasks, Roma *et al.* [14] published an informed guidance on their construction, showing that price density(i.e. number of prices utilized) affected the estimation of demand indices. In a recent meta-analysis, price density moderated the relationship between P_{max}, breakpoint and measures of quantity-frequency of illicit drug use [15], suggesting that the APT concurrent validity might also be affected by structural characteristics. This is important, as the evolving literature has used a variety of APT versions with prices ranging from 13 to 51 [16,17]. However, their impact over the relationship between each APT index and alcohol-related variables has yet to be systematically examined.

More generally, APT research has revealed heterogeneous estimates of associations between demand indices and alcohol-related variables. In attempts to synthesize these findings, two studies have meta-analyzed studies published up to 2015 [18] and 2017 [19]. Results from the first study showed that intensity and, to a lesser extent, O_{max}, exhibited meaningful effect sizes, but the other demand indices were not implicated, which raised doubts about the validity of the APT. More recently, Zvorsky *et al.*[19] also supported the contribution of intensity and O_{max}, but its general scope and the fact that all alcohol use indicators were collapsed, precluded from examining specific associations between the APT indices and different patterns of alcohol use. Also, the moderating effects of individual (e.g. sex) and APT-related characteristics (e.g. price density, APT's indices transformation) were not explored, leaving the above-mentioned concerns as open questions. A recent meta-analysis of illicit drug demand found that females exhibited stronger correlations between P_{max}, breakpoint and quantity–frequency and severity of illicit drug use [15]. However, the moderating role of sex in the association between alcohol demand indices and alcohol use has not been meta-analytically appraised. Given the existing sex and gender differences in terms of alcohol use and alcohol-related problems [20,21] and the high variation in female percentages in the preceding APT meta-analyses [18,19], the potential moderating role of sex warrants further examination.

The current systematic review and meta-analysis addresses a number of the preceding gaps on the APT literature and entails an extension of previous existing meta-analyses [18,19]. It is a comprehensive and updated meta-analytical examination of the concurrent validity of the APT. Specifically, it sought to (1) meta-analyze the findings on cross-sectional relationships between APT indices, patterns of alcohol use (i.e. quantity of alcohol use, number of heavy drinking episodes) and negative consequences (i.e. alcohol-related problems, hazardous drinking), (2) to test potential moderators of the observed associations (i.e. sex, year of publication and APT-related characteristics) and (3) to assess the presence of small study effects.

METHOD

Literature search procedure and data extraction

Prior to the onset of the meta-analysis, a comprehensive protocol detailing the methods and procedures adopted was registered in the International Prospective Register of Systematic Reviews (PROSPERO) system for systematic reviews (ID: CRD42019137512) and published independently [22]. Both the review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) statement [23] (see Supporting information, Table S1). Potential eligible studies were identified via searches of PubMed, PsycINFO, Scopus and Web of Science databases. As the first APT paper was published in 2006 [8], literature searches were conducted from inception to October, 2020 using the Boolean search terms that follow: (alcohol) AND (behavioral economic*) OR (purchase task) OR (alcohol demand) OR (reinforcing efficacy) OR (reinforcing value). Peer-review studies were retained for the meta-analysis if they met the following criteria: (1) were human studies; (2) were experimental or clinical studies analyzing the relationship between at least one baseline individual-level APT index and alcohol-related variables (i.e. alcohol use, binge drinking, alcohol-related problems, hazardous drinking). Because *in-vivo* laboratory studies using state-based APTs are qualitatively different from trait-based assessments indices [10,11,24,25], experimental studies using state-based APT versions were excluded. Also, data on elasticity of demand were only included when calculated through the two most widely used formulae [26,27]. When the same sample was used in more than one study, the study providing more information and a higher number of participants was retained. The ‘participants’ and ‘procedure’ sections of studies potentially based on the same dataset were compared to ensure their independence. In case of questions, corresponding authors were contacted to clarify this point. Finally, studies using other demand measures different than an APT, not reporting data at individual level or not reporting baseline data on either APT or alcohol-related variables were excluded.

The literature search was conducted by two reviewers who coded the studies independently on the following variables: authors (names), tittle (name), year of publication (year), country (name), sample characteristics (sample size, mean age, proportion of study participants who were female), APT-related characteristics (number and range of prices, type of APT’s indices transformation), alcohol variables (questionnaire, unit of measure) and outcome measures (Pearson’s or Spearman’s coefficient effect sizes). No disagreement occurred regarding potential eligible studies. A total of 20 authors leading 35 studies were also contacted to provide the necessary data to conduct the meta-analysis. Of these, 18 provided the necessary data to permit inclusion of 32 studies in the meta-analysis.

Meta-analytical approach

Pearson’s and Spearman’s effect size correlations were used as primary effect sizes on the association between APT indices (intensity, elasticity, O_{max}, P_{max} and breakpoint) and alcohol-related variables. Given the marked heterogeneity in study designs (i.e. treatment-seeking or community samples) and methods (i.e. variability in alcohol measures and APT-related characteristics), a random-effects model was adopted. Spearman’s correlations were converted into Pearson’s using the formula: $r = 2*\sin(r_s \pi/6)$ [28]. Cochran’s Q, I^2 and tau (τ) were computed to characterize heterogeneity; $I^2 \leq 25\%$ suggests low heterogeneity, ~50% suggests moderate heterogeneity and ≥ 75% suggests high heterogeneity across studies [29]. Additionally, a 95% prediction interval was calculated following the formula reported by IntHout *et al.* [30]. To complement these analyses, a leave-one-out ‘jackknife’ sensitivity analysis was carried out. It consists of evaluating effect sizes with each study excluded and identifies studies with large contributions on the overall effect sizes, which can distort the pooled effect [31]. Systematic differences in effect sizes based on the alcohol-related variables (alcohol use, heavy drinking, alcohol-related problems and hazardous drinking) were also explored. Sex, year of publication and APT-related characteristics (i.e. number of APT prices and type of APT's indices transformation used) were also assessed as potential moderators on the obtained estimates using meta-regressions at a two-sided 95% confidence level ($P < 0.05$). When performing meta-regressions on the effect of price density, one outlying value (i.e. 51 prices) in the study by Salzer *et al.* [16] was winsorized, as recommended by Tabachnick & Fidell [32]. Based on the substantial heterogeneity of type of transformation used to correct for skewness and kurtosis across APT studies, a subgroup analysis of the observed associations by type of transformation (square root, log-based or none) was conducted as well. A thorough procedure was followed to assess for small-study effects using non-parametric and regression-based tests [33]: (1) the two-tailed Begg–Mazumdar test (i.e. rank correlation between the standard effect size and their variances, with deviations from zero indicating the presence of small study effects), and (2) the two-tailed Egger's test (i.e. asymmetry of the funnel plot with intercept values close to zero indicating lesser small study effects). Sensitivity analysis was subsequently performed following the Duval & Tweedie's trim-and-fill approach (i.e. computation of the effect sizes after imputation of estimated missing studies) using the L_0 estimator and exploring missing studies to the left of the mean, except for elasticity due to its inverse association. Despite sometimes leading to conservative results [34], this popular approach improves pooled estimates [35] and is considered as adequate [36]. No risk of bias assessment was performed.

RESULTS

Sample characteristics

Figure 1 depicts the PRISMA flow-chart on the review process. A total of 20 736 studies were initially identified. After removing duplicates, 17 705 records were screened at title and abstract levels and were discarded if they were not relevant to the study question. The 109 potentially relevant studies were assessed for eligibility. A total of 50 papers containing 52 studies were finally retained after applying the exclusion criteria.

Study characteristics are shown in Table 1. The median sample size was 191 (total sample size = 18 466; range = 36–4790) and participants' mean age was 25.14 [standard deviation (SD) = 4.77] years. Females comprised 0–90.6% of the sample, with a weighted percentage of43.32%. APT structural characteristics varied substantially in terms of number of prices (range = 9–51) and maximum price (range = $9–1120). This latter range is significantly reduced if the two studies [37,58] with extreme maximum prices (i.e. $100 and $1120, respectively) are removed (range = $9–40). Raw intensity (58.00%, $n = 29$), O_{max} (54.35%, $n = 25$), P_{max} (62.16%, $n = 23$), breakpoint (74.42%, $n = 32$) and elasticity (56.82%, $n = 25$) were used in most bivariate associations, followed by the logarithmic (%: 24.00, 15.22, 18.92, 6.98, 22.73; *n*: 12, 7, 7, 3, 10, respectively) and square root (%: 18.00, 30.43, 18.92,18.60, 20.45; *n*: 9, 14, 7, 8, 9, respectively) transformations. Of note, 88.46% of studies ($n = 46/52$) were conducted in the United States.

Average effect sizes and heterogeneity analyses

Table 2 shows results on primary meta-analytical analyses and its associated heterogeneity calculations. Forest plots are presented in Data S1. All demand indices were significantly associated with all alcohol-related outcomes except for P_{max}, which was significantly associated with alcohol-related problems only ($r = 0.064$, $P = 0.004$). Significant effect sizes showed a wide range ($r = 0.064–0.494$), with intensity exhibiting moderate-to-large effect sizes ($r = 0.334–0.494$), elasticity low-to-moderate (r = [C0]0.197 to [C0]0.132) and O_{max} moderate ($r = 0.230–0.354$). Effect sizes for breakpoint ($r = 0.137–0.155$) and P_{max} ($r = 0.007–0.064$) were small in magnitude. An analysis by alcohol variable showed larger effects of intensity ($Q_{(3)} = 34.79$, $P < 0.001$) on alcohol use compared to heavy drinking and alcohol-related problems ($r = 0.494$ versus 0.383 and 0.334, respectively) and on hazardous drinking ($r = 0.437$) compared to alcohol-related problems ($r = 0334$). The magnitude of the O_{max}-alcohol use association was greater ($Q_{(3)} = 16.623$, $P = 0.001$) than those observed for hazardous drinking and alcohol-related problems ($r = 0354$ versus 0.239 and 0.230, respectively). Breakpoint ($Q_{(3)} = 0.557$, $P = 0.906$), elasticity ($Q_{(3)} = 2.282$, $P = 0.516$) and P_{max} ($Q_{(3)} = 4.315$, $P = 0.229$) did not differ across the assessed alcohol-related variables.

Results based on I^2 suggested a moderate-to-high heterogeneity in most relationships (see Table 2). Standard deviations of effect sizes across studies as computed by the τ statistic suggested heterogeneity for intensity in alcohol use ($\tau = 0.115$) and heavy drinking ($\tau = 0.132$), and for elasticity in alcohol use ($\tau = 0.124$), heavy drinking ($\tau = 0.145$) and alcohol-related problems for elasticity ($\tau = 0.126$). Variations in confidence intervals between the overall analyses and the jackknife approach were small, suggesting a minimal impact of individual studies on the overall effects. The only exception was the lower limit of the P_{max}-heavy drinking and the elasticity–heavy drinking associations, which increased by 5.1 and 5.6%, respectively, when the study by Bertholet *et al*. [42] was removed. This study also provided the lowest effect size limits in 50% ($n = 10/20$) of the estimated effect sizes.

Moderation analyses

Regarding sex as a moderator, meta-regression analyses showed statistically significant effects of sex over intensity and elasticity effect sizes (see Table 3). Specifically, increased percentage of females strengthened the association between intensity and alcohol use ($P = 0.025$), alcohol-related problems ($P = 0.001$) and hazardous drinking ($P < 0.001$) and reduced the effect of elasticity on hazardous drinking ($P = 0004$). In terms of year of publication, more recent studies reported greater effect sizes between intensity and hazardous drinking ($P = 0.048$), P_{max} and alcohol-related problems ($P = 0.020$) and smaller effect sizes between elasticity and hazardous drinking ($P = 0.045$).

With regard to APT assessment characteristics, meta-regressions showed non-significant effects of number of prices on any of the tested associations (Ps = 0.096–0.888). The type of index transformation significantly moderated the effect sizes for the heavy drinking variables. More precisely, square-root elasticity ($Q_{(2)} = 22.41$, $P < 0.001$) yielded a larger effect size (r = [C0]0.729, $n = 1$) than the log (r = [C0]0.231, $n = 4$) and untransformed ones (r = [C0]0.083, $n = 6$).

Small study effects

According to the Begg–Mazumbar and the two-sided Egger's tests, there was no evidence of small study effects in 85% of the associations (see Table 4). The exceptions included Egger's test in the association between O_{max} and alcohol use; elasticity and hazardous drinking; and in the breakpoint–heavy drinking association. Despite these significant associations, they may be attributable to its high between-study heterogeneity, as suggested by the Q, I^2 and τ-statistics (see Table 2).

Finally, the Duval & Tweedie's trim-and-fill procedure suggested the influence of nine potential unpublished studies on the association between elasticity and alcohol use and one for the intensity-hazardous drinking association (see Table 4). The imputation of these potentially unreported studies decreased the estimated effect size for elasticity–alcohol use by 26.9% (from [C0]0.197 to [C0]0.144), and for intensity–hazardous drinking by 1.14% (from 0.437 to 0.432).

DISCUSSION

This systematic review and meta-analysis provides a comprehensive, updated account of the APT's concurrent validity in the burgeoning literature in this area, and addresses how a number of other variables affect its links with diverse aspects of alcohol involvement. All the demand indices except P_{max} were significantly associated with all alcohol-related outcomes, although with substantial differences in effect sizes. The greatest associations were evinced between intensity and all alcohol outcomes and between O_{max} and alcohol use. Results also suggested significant effects of sex, year of publication and type of APT's indices transformation on meta-analytical findings. Lastly, some evidence of small study effects was obtained, especially for elasticity and alcohol use. Nonetheless, meta-analytical estimates based on imputed effects did not substantially alter the significance or magnitude of effects.

Moderate-to-large effect sizes were observed for intensity, moderate for O_{max} and small for elasticity and breakpoint. Similar results have been noted in meta-analyses of cross-sectional relationships with the demand for cigarettes [82] and illicit drugs [15], which indicates that these associations generalize across substances. The reported variations in effect sizes across APT indices converges with the multi-dimensional nature of drug-reinforcing efficacy [7] and they highlight the relevance of demand volumetric characteristics (intensity and O_{max}) in relation to alcohol misuse [83], often comprising the 'amplitude' latent component of demand [83,84]. Notably, in-treatment reductions of these indices predict alcohol use outcomes after a brief intervention [85], and they are the most sensitive indices to experimental manipulation of individuals' contexts through cue exposure, increased stress/negative affect, opportunity cost or behavioral interventions [86]. More generally, findings support the validity of briefer assessments of alcohol demand to zero in on intensity and O_{max}. While intensity captures the unconstrained reinforcing value of alcohol (i.e. consumption at no cost), O_{max} has been suggested to capture the most relevant features of motivation in the context of constraint [83], represented by the maximum effort (i.e. expenditure) deployed to obtain the drug. As such, these indices may inform about the magnitude of constraints or alternative reinforcers that should be implemented in preventive (e.g. availability and accessibility) and treatment (e.g. contingency management) interventions to compete against alcohol use.

Variations in effect sizes were partially explained by several variables. Sex worked as moderator on several of the observed effects for elasticity and intensity. Studies with a greater proportion of females strengthened the associations between intensity and alcohol use, related-problems and hazardous drinking. However, the elasticity and hazardous drinking association was weakened by female sex. Contrary to recent findings in illicit drugs [15], these results suggest the relevance of the volumetric demand characteristics regarding explaining alcohol involvement in females, which may be driven by biological factors related to higher sensitivity to alcohol [20]. Even though females may consume less alcohol than males, they are more vulnerable to alcohol effects and have exacerbated medical and interpersonal difficulties [87,88], which may account for higher magnitude effects for intensity on alcohol use, related problems and hazardous drinking. Finally, as alcohol use in men is considered more normative and is generally higher epidemiologically, it may be that demand in females taps intrinsic alcohol-reinforcing values more incisively. In other words, higher demand in females may be more specific to alcohol reinforcing properties itself, and thus be more clinically significant than higher demand in males. On another note, the reduced association between pricing-related indices (i.e. elasticity) and hazardous drinking observed in samples with a greater percentage of females suggests a relatively lower impact of price-based policies on females' demand compared to men. That is, as females reach higher blood alcohol concentrations (BACs) than males (i.e. present more sensitivity to alcohol), even at same alcohol doses, they may assume higher unit costs [89], especially in the context of drinking to cope [90].

The contribution of drinking motives may play a role on accounting for such effects, commensurate with studies reporting its mediating effect on the relationship between alcohol demand, alcohol use and related problems in college and adult samples [45]. Drinking motives, particularly social and drinking to cope, have been linked to female sex in pre-clinical [91] and human research [92], and has been suggested to modulate the effect of alcohol-reinforcing efficacy and alcohol use and problems [45,81,90]. These drinking motives could lead to social/interpersonal, job and financial strains which map onto several of the items contained on the scales used to measure alcohol use consequences.

Year of publication also moderated several of the observed associations. We found a strengthened effect for the intensity-hazardous drinking association in more recent studies. The fact that the Alcohol Use Disorders Identification Test (AUDIT) is being increasingly used to assess this pattern of alcohol use symptoms may partially account for this finding. More precisely, more than 83.3% (10 of 12) of the studies published from 2017 to 2020 used the AUDIT compared to 70% (seven of 10) of studies published from 2006 to 2016. Given that the AUDIT includes frequency and quantity items and because they are highly correlated to intensity, this finding might be arguably attributed to this methodological element, rather than changes in sample characteristics or other variables. This may also account for the apparent contradiction of the diminishing association across years between elasticity and hazardous drinking. Despite that more recent studies used more balanced samples in terms of sex, and a lower percentage of females is associated with an increasing association between elasticity and hazardous drinking, the growing use of the AUDIT for assessing hazardous drinking may lead to a lower relevant role of elasticity on deleterious alcohol use patterns compared to other measures (e.g. DSM criteria). However, this remains speculative, as this hypothesis could not be tested directly.

The use of different mathematical transformations of APT's indices has yielded significant variation in the studied associations. In more recent studies there was an increasing use of logarithmic over square-root transformations, which consistently produced lower effects in moderation analyses, and may also help to explain the reduced correlations between elasticity and hazardous drinking across years. What is somewhat concerning is that virtually no study provided a detailed justification for using one or other transformation or reported changes in measures of dispersion. Importantly, transforming data in most circumstances does not reduce variability [93] and non-transformed indices in some ways may be more desirable on a theoretical and practical level, but obviously have trade-offs in terms of meeting typical statistical assumptions. Reporting both transformed and non-transformed data in the Supporting information might help to generalize findings beyond individual studies. Back-transformation is a commonly accepted practice [94,95], although it is only recommended for means and confidence intervals.

Some limitations inherent to the reviewed studies should be considered. The percentage of females was calculated based on socio-demographic characteristics and not on participants with valid APT data. Nonetheless, excluded participants are usually minimal, and consequently using this percentage may cause minimal deviation. This meta-analysis did not address the potential influence of psychiatric comorbidities in the reported effect sizes, as most studies were based on the general population; nor did it address other APT structural characteristics, such as the vignette instructions, which warrants further consideration. Also, the small number of works reporting each alcohol-related indicator reduces power in moderation analyses, and no risk of bias assessment was performed. The cross-sectional nature of this study reflects the state of the literature, but limits the extent to which the role of demand in the etiology or progression of alcohol misuse can be addressed. Finally, as conclusions are drawn based on aggregated samples, this meta-analysis cannot rule out potential ecological bias (i.e. systematic differences between individual- and group-level effects). The study also has several strengths that are worthy of mention. Besides using a pre-registered, peer-reviewed and published protocol and following a comprehensive search strategy, the present meta-analysis examined the effect sizes of APT indices regarding multiple alcohol-related variables and covered different patterns of alcohol use involvement. Also, it included several potentially relevant moderators of such effects and assessed small study effects using multiple metrics.

In summary, the present results provide a comprehensive up-to-date review of the concurrent validity of alcohol demand as measured by the APT in relation to alcohol misuse. Intensity and O_{max} are the most relevant to account for alcohol use involvement, and exhibit the highest promise to ultimately be used as diagnostic or prognostic tools. There has been a recent increasing interest to use demand levels as clinical tools that would trigger the use of different treatment intensities or modalities. In this sense, APT measures would be of help to identify subgroups of individuals for whom specific interventions are particularly effective. The fact that the association between APT and alcohol involvement was moderated by sex suggests different maintaining or etiological variables for alcohol use. For example, as problems in emotional regulation are more relevant in females, and given that intense negative affect is believed to enhance the reinforcing efficacy of alcohol [52], the former may be an important gender-related risk factor leading to more problematic use and poor treatment response. Finally, it is worth noting that although the current systematic review and meta-analysis is supportive of the concurrent validity of alcohol demand as measured by the APT, it cannot speak to the etiological or maintaining role of alcohol demand. This meta-analysis suggests robust correlations (particularly for intensity and O_{max}) but cannot speak to causation. Longitudinal studies on demand remain scarce, making them a high priority for the future.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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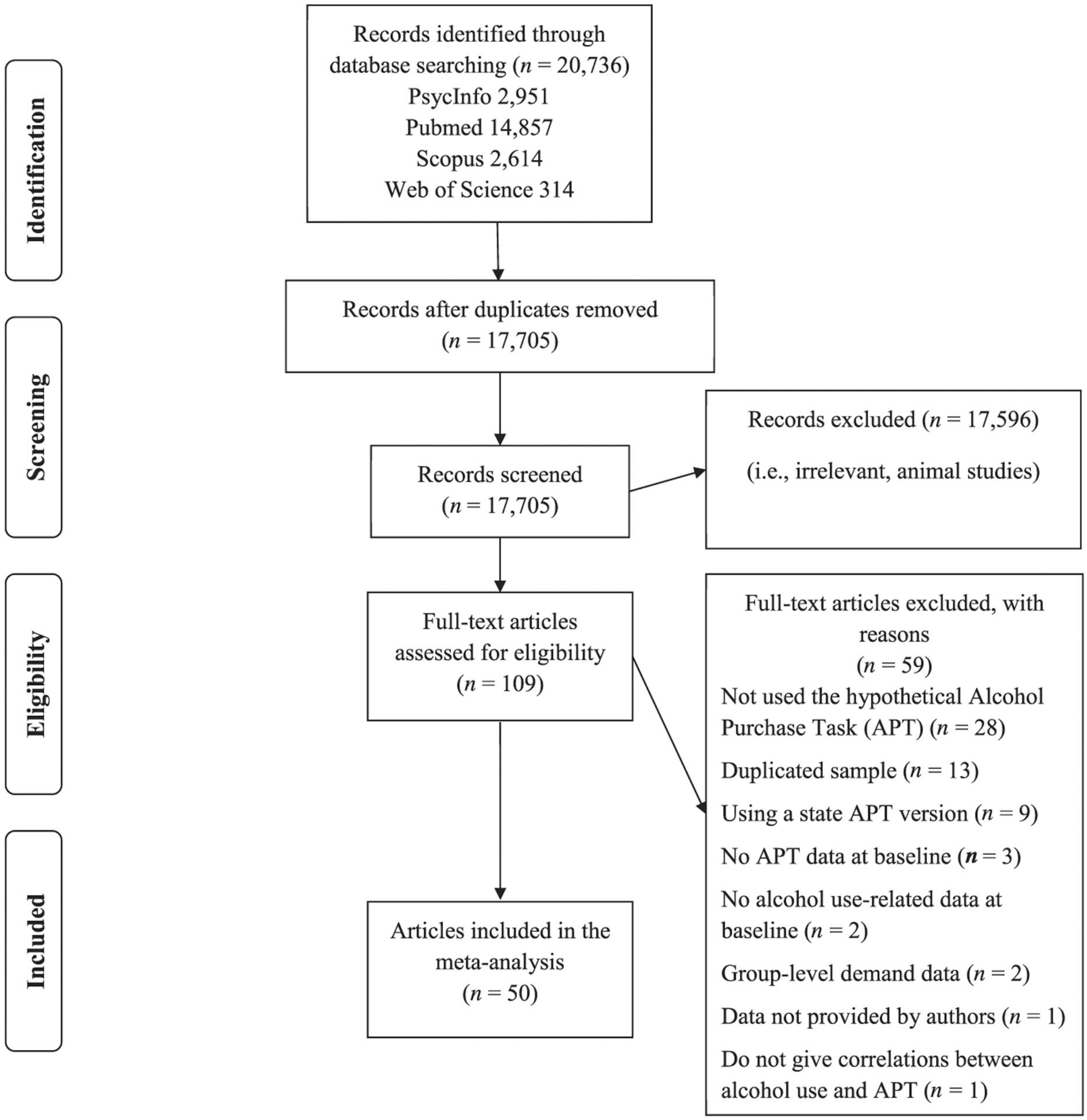

Figure 1.
Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow-chart on the literature search procedure

Table 1

Study characteristics

Study	Country	Sample size	Sex (% females)	Age, mean (SD)	Structural APT characteristics: Number of prices	Structural APT characteristics: Price range	Alcohol-related measures Alcohol use: Alcohol use	Heavy drinking	Alcohol-related problems	Hazardous drinking
Acker *et al.* 2012 [37]	USA	61	42.60	23.80 (5.40)	25	\$0–100	Drinks/week[a]			AUDIT
Acuff *et al.* 2020a [38]	USA	274	42.9	25.15 (4.10)	23	\$0–22	Drinks/week[b]		YAACQ	
Acuff *et al.* 2020b [39]	USA	602	57.3	22.63 (1.03)	30	\$0–40	Drinks/week[b]		YAACQ	
Amlung *et al.* 2013 [40]	USA	273	73.00	20.00 (1.70)	21	\$0–10	Drinks/week[b]			AUDIT
Amlung *et al.* 2015 [41]	USA	85	52.00	22.94 (3.41)	21	\$0–30	Drinks/week[c]		YAACQ	
Amlung *et al.* 2017 [12]	USA	111	42.00	36.18 (12.86)	24	\$0–35	Drinks/week[a]			DSM-IV
Bertholet *et al.* 2015 [42]	Switzerland	4790	0.00	21.20 (1.20)	11	\$0–20[c]	Drinks/week	Binge/ month		DSM-5
Cassidy *et al.* 2019 [43]	USA	167	42.7	18.14 (0.97)	17	\$0–20	Drinks/occasion[a]			
Dennhardt *et al.* 2015 [44]	USA	97	58.80	20.10 (2.23)	19	\$0–20	Drinks/week[b]	Binge/ month	YAACQ	
Dennhardt *et al.* 2016 [45]	USA	68	8.80	32.31 (8.84)	19	\$0–20	Drinks/month[a]			
Gray & MacKillop 2014 [46]	USA	720	39.00	29.70 (12.00)	21	\$0–35				AUDIT
Herschl *et al.* 2012 [47]	USA	297	54.20	19.88 (1.92)	14	\$0–9			RAPI	AUDIT
Hochster *et al.* 2018 [48]	USA	69	52.00	21.40 (2.20)	14	\$0–20	Drinks/occasion[a]	Binge/90-days		AUDIT
Joyner *et al.* 2019 [49]	USA	370	61.10	18.75 (1.03)	17	\$0–20	Drinks/week[b]		YAACQ	
Kaplan *et al.* 2017 [50]	USA	179	47.49	37.53 (12.69)	16	\$0–20	Drinks/week	Binge/ month		
Kaplan & Reed 2018 [51]	USA	721	55.30	35.50 (10.92)	11	\$0–10	Drinks/week[b]	Binge/ month		
Kiselica & Borders 2013 [52]	USA	202	83.66	19.48 (1.42)	19	\$0–15	Drinks/week[b]		YAACQ	
Lemley *et al.* 2016 [53]	USA	80	72.50	19.50 (18.70–20.64)[d]	16	\$0–12			YAACQ	

					Structural APT characteristics		Alcohol-related measures Alcohol use			
Study	Country	Sample size	Sex (% females)	Age, mean (SD)	Number of prices	Price range	Alcohol use	Heavy drinking	Alcohol-related problems	Hazardous drinking
Lemley *et al.* 2017 [54]	USA	85	90.60	20.00 (19.50–21.00)[d]	24	$0–30	Drinks/week[b]			
Luciano *et al.* 2019 [55]	USA	91	36.26	26.53 (2.69)	14	$0–9	Drinks/week[b]		YAACQ	
Luehring-Jones *et al.* 2016 [56]	USA	36	61.00	19.60 (1.90)	14	$0–9	Drinks/occasion[a]	Binge/90-days		AUDIT
MacKillop & Murphy 2007 [57]	USA	54	67.00	20.00 (1.22)	14	$0–9	Drinks/week[b]	Binge/week	RAPI	
MacKillop *et al.* 2010 [58]	USA	61	38.00	42.40 (13.10)	16	$0–1120	Drinks/week[a]	% HDD		DSM-IV
Martinetti *et al.* 2019 [59]	USA	132	80.30	19.50 (1.42)	19	$0–15	Drinks/week[b]			AUDIT
	France	132	75.80	21.25 (4.42)	19	$0 – 22[c]	Drinks/week[b]			AUDIT
Merrill & Aston2020 [60]	USA	95	52.00	18.67 (0.66)	14	$0–9	Drinks/week[b]		BYAACQ	
Meshesha *et al.* 2020 [61]	USA	41	31.70	38.24 (12.69)	17	$0–20	Drinks/occasion[a]	Binge/month		DSM-5
Minhas *et al.* 2020 [62]	Canada	730	47.40	21.44	30	$0–40			YAACQ	
	USA[e]	602	42.70	22.63	30	$0–40			YAACQ	
Morrell *et al.* 2020 [63]	USA	131	78.60	19.47 (1.67)	9	$0–30	Drinks/week[b]		BYAACQ	AUDIT
Morris *et al.* 2017 [64]	USA	865	59.00	32.85 (11.15)	21	$0–15				AUDIT
Morris *et al.* 2018 [65]	Canada	1364	54.90	35.11 (10.79)	30	$0–18[c]				AUDIT
Murphy & MacKillop 2006 [8]	USA	267	76.00	20.11 (1.47)	14	$0–9	Drinks/week[b]	Binge/week	RAPI	
Murphy *et al.* 2009 [66]	USA	38	50.00	19.92 (1.68)	14	$0–9	Drinks/week[a]	Binge/month	YAAPST	
Murphy *et al.* 2013 [67]	USA	133	49.60	–	17	$0–20	Drinks/week[b]	Binge/month		
Naude *et al.* 2020 [68]	USA	185	81.00	19.96 (3.14)	13	$0–9				AUDIT
Noyes *et al.* 2018 [69]	USA	529	46.60	33.00 (8.85)	14	$0–9	Drinks/occasion[f]		DrInC	AUDIT
Patel *et al.* 2019 [70]	Canada	926	53.90	38.20 (13.70)	30	$0–28[c]	Drinks/week			
Ramirez *et al.* 2016 [71]	USA	223	58.74	18.60 (0.70)	19	$0–20	Drinks/week[b]			AUDIT

Study	Country	Sample size	Sex (% females)	Age, mean (SD)	Structural APT characteristics		Alcohol-related measures Alcohol use			
					Number of prices	Price range	Alcohol use	Heavy drinking	Alcohol-related problems	Hazardous drinking
Ramirez *et al.* 2020 [72]	USA	480	59.60	21.90 (1.73)	19	$0–20	Drinks/week[b]			
Rose *et al.*2018 [13]	UK	62	46.77	22.35 (4.24)	25	$0 – 18[c]	Drinks/week[a]			AUDIT
Salzer *et al.* 2019 [16]	USA	98	50.00	32.99 (–)	51	$0–20	Drinks/week[b]			
Skidmore *et al.* 2014 [73]	USA	207	53.00	19.50 (1.99)	17	$0–20	Drinks/week[b]		YAACQ	
Smith *et al.* 2010 [74]	USA	255	73.30	20.55 (4.30)	17	$0–20	Drinks/week[b]		YAACQ	
Strickland *et al.* 2017 [75]	USA	139	54.70	31 (26–39)[d]	16	$0–140	Drinks/week	Binge/ month[g]		
Strickland *et al.* 2019 [17]	USA	223	52.90	35.20 (10.50)	13	$0–11	Drinks/week			AUDIT
Teeters *et al.* 2014 [76]	USA	207	53.10	19.50 (1.99)	17	$0–20	Drinks/week[b]			
Teeters & Murphy 2015 [77]	USA	328	75.30	20.47 (2.63)	17	$0–20	Drinks/week[b]	Binge/ month		
Tripp *et al.* 2015 [78]	USA	264	77.00	21.70 (5.00)	17	$0–20	Drinks/week[a]		YAACQ	
Tucker *et al.* 2016 [79]	USA	191	23.56	50.09 (11.94)	18	$0–20	Drinks/week[a]		DPS	ADS
Wahlstrom *et al.* 2012 [80]	USA	120	0.00	19.88 (1.83)	14	$0–9			RAPI	AUDIT
Yurasek *et al.* 2011 [81]	USA	215	72.00	20.65 (4.14)	17	$0–20	Drinks/week[b]	Binge/ fortnight	YAACQ	

APT = Alcohol Purchase Task; AUDIT = Alcohol Use Disorder Identification Test; YAACQ = Young Adult Alcohol Consequences Questionnaire; DSM = Diagnostic and Statistical Manual of Mental Disorder; RAPI = Rutgers Alcohol Problem Index; HDD = heavy drinking days; BYAACQ = Brief Young Adult Alcohol Consequences Questionnaire; YAAPST = Young Adult Alcohol Problems Screening Test; DrInC = Drinker Inventory of Consequences; DPS = Drinking Problems Scale; ADS = Alcohol Dependence Scale; SD = standard deviation.

[a]Time-line follow-back;

[b]daily drinking questionnaire;

[c]original values converted to US dollars;

[d]median (interquartile range);

[e]the US sample comes fromthe same set as Acuff's study [39]. Nonetheless, as associations are reported regarding different alcohol outcomes, both studies were retained in the meta-analysis. Aggregated sample size and weighted sex proportion were calculated using only one of the samples;

[f]drinking history questionnaire;

[g]National Institute on Alcohol Abuse and Alcoholism recommended alcohol questions.

Table 2

Effect sizes and heterogeneity on the associations between alcohol demand, alcohol use, heavy drinking, alcohol-related problems and hazardous drinking

Demand index	k	n	r_{RE}	95% CI	P	r_{osr}	Q	P_Q	I^2	τ	95% PI
Alcohol use											
Intensity	43	13 623	0.494	0.461, 0.526	$< 10^{-8}$	0.457, 0.533	196.08	$<10^{-3}$	78.58	0.115	0.071, 0.917
O_{max}	38	12 842	0.354	0.320, 0.387	$< 10^{-8}$	0.313, 0.392	118.19	$< 10^{-3}$	68.69	0.087	0.153, 0.555
P_{max}	28	10 814	0.017	−0.012, 0.045	0.254	−0.020, 0.052	37.02	0.095	07.07	0.035	0.014, 0.020
Breakpoint	34	11681	0.137	0.106, 0.169	$< ^{-8}$	0.098, 0.177	63.65	0.001	48.16	0.057	0.091, 0.183
Elasticity	35	11495	−0.197	−0.245, −0.148	$< 10^{-8}$	−0.255, −0.139	174.50	$< 10^{-3}$	80.52	0.124	−0.342, −0.052
Heavy drinking											
Intensity	14	7132	0.383	0.309, 0.452	$< 10^{-8}$	0.269, 0.469	78.21	$< 10^{-3}$	83.38	0.132	0.186, 0.580
O_{max}	13	6993	0.295	0.226, 0.361	$< 10^{-8}$	0.204, 0.373	49.62	$< 10^{-3}$	75.82	0.103	0.184, 0.406
P_{max}	11	6568	0.019	−0.005, 0.044	0.116	−0.056, 0.052	8.75	0.556	$< 10^{-3}$	$< 10^{-3}$	0.018, 0.020
Breakpoint	13	6625	0.155	0.117, 0.192	$< 10^{-8}$	0.088, 0.200	14.26	0.284	15.86	0.027	0.138, 0.172
Elasticity	11	6137	−0.179	−.277, −0.077	$< 10^{-3}$	−0.333, −0.053	58.79	$< 10^{-3}$	82.99	0.145	−0.283, −0.075
Alcohol-related problems											
Intensity	22	5665	0.334	0.288, 0.378	$< 10^{-8}$	0.279, 0.386	68.34	$< 10^{-3}$	69.27	0.095	0.180, 0.488
O_{max}	22	5556	0.230	0.185, 0.274	$< 10^{-8}$	0.177, 0.281	56.12	$< 10^{-3}$	62.58	0.083	0.139, 0.321
P_{max}	15	4196	0.064	0.021, 0.107	0.004	0.012, 0.117	23.89	0.047	41.39	0.052	0.051, 0.077
Breakpoint	18	4731	0.142	0.105, 0.178	$< 10^{-8}$	0.097, 0.185	24.97	0.095	31.91	0.043	0.115, 0.169
Elasticity	17	4611	−0.132	−0.201, −0.063	$< 10^{-3}$	−0.214, −0.046	81.96	$< 10^{-3}$	80.48	0.126	−0.200, −0.063
Hazardous drinking											
Intensity	22	10 509	0.437	0.390, 0.482	$< 10^{-8}$	0.383, 0.492	113.64	$< 10^{-3}$	81.52	0.108	0.197, 0.677
O_{max}	17	9868	0.239	0.176, 0.299	$< 10^{-8}$	0.148, 0.321	98.85	$< 10^{-3}$	83.81	0.109	0.131, 0.347
P_{max}	16	8875	0.007	−0.036, 0.050	0.757	−0.050, 0.063	30.59	0.010	50.96	0.051	0.006, 0.008
Breakpoint	18	9868	0.139	0.098, 0.180	$< 10^{-8}$	0.083, 0.189	41.12	0.001	58.66	0.058	0.104, 0.174
Elasticity	20	10 090	−0.181	−0.220, −0.141	$< 10^{-8}$	−0.230, −0.134	44.81	0.001	57.60	0.059	−0.230, −0.132

k = number of studies; n = sample size; r_{RE} = zero-order Pearson correlations from the random effects model; 95% CI = 95% confidence interval; r_{OSR} = range of effect sizes from the one-study-removed analysis; Q = Cochran's Q-test of homogeneity; P_Q = P-value corresponding to Cochran's Q; I^2 = Proportion of variation across studies due to heterogeneity; τ = standard deviations of effect sizes across studies; 95% PI = 95% prediction interval.

Table 3

Meta-regressions and subgroup analyses

	Sex		Year of publication		Number of prices		Type of transformation			
							Effect sizes			
Demand index	B (SE)	P	B (SE)	P	B (SE)	P	Raw	Log	Square root	Q
Alcohol use										
Intensity	**0.003 (0.001)**	**0.025**	−0.010 (0.006)	0.125	0.002 (0.004)	0.697	**0.513**	**0.437**	**0.505**	4.00
O_{max}	−0.001 (0.001)	0.606	−0.006 (0.005)	0.235	0.001 (0.004)	0.790	**0.363**	**0.319**	**0.374**	2.31
P_{max}	< −0.001 (0.001)	0.728	0.001 (0.004)	0.790	< 0.001 (0.002)	0.878	**0.040**	−0.019	0.016	3.19
Breakpoint	0.001 (0.001)	0.242	−0.003 (0.005)	0.536	0.002 (0.003)	0.429	**0.131**	**0.140**	**0.152**	0.25
Elasticity	0.001 (0.002)	0.610	−0.014 (0.007)	0.058	−0.001 (0.005)	0.888	**−0.173**	**−0.264**	**−0.244**	3.64
Heavy drinking										
Intensity	0.002 (0.003)	0.413	−0.014 (0.010)	0.150	0.006 (0.013)	0.612	**0.388**	**0.312**	**0.554**	6.18
O_{max}	< −0.001 (0.002)	0.806	−0.010 (0.009)	0.263	−0.010 (0.016)	0.537	**0.317**	**0.221**	**0.493**	13.64
P_{max}	−0.001 (0.001)	0.180	−0.007(0.005)	0.173	−0.005 (0.007)	0.502	**0.026**	0.007	−0.018	0.30
Breakpoint	−0.001 (0.001)	0.162	−0.005 (0.006)	0.418	−0.005 (0.005)	0.384	**0.149**	0.132	**0.132**	0.13
Elasticity	0.001 (0.003)	0.798	−0.012 (0.013)	0.367	−0.006 (0.017)	0.701	−0.083	**−0.231**	**−0.729**	22.41
Alcohol-related problems										
Intensity	**0.004 (0.001)**	**< 0.001**	−0.009 (0.006)	0.148	0.002 (0.005)	0.707	**0.321**	**0.361**	**0.348**	0.603
O_{max}	0.002 (0.001)	0.190	0.002 (0.006)	0.686	0.003 (0.004)	0.494	**0.225**	0.189	**0.268**	0.80
P_{max}	0.001 (0.001)	0.642	**0.010 (0.004)**	**0.020**	0.001 (0.003)	0.794	**0.056**	-	0.141	0.80
Breakpoint	0.001 (0.001)	0.308	0.002 (0.004)	0.617	0.002 (0.003)	0.586	**0.149**	-	0.189	0.05
Elasticity	−0.001 (0.002)	0.582	−0.011 (0.008)	0.176	−0.007 (0.005)	0.180	**−0.108**	−0.050	−0.207	1.14
Hazardous drinking										
Intensity	**0.004 (0.001)**	**< 0.001**	**0.020 (0.010)**	**0.048**	0.002 (0.006)	0.742	**0.409**	**0.455**	**0.491**	3.79
O_{max}	0.002 (0.002)	0.386	0.002 (0.013)	0.891	0.004 (0.007)	0.526	**0.195**	**0.157**	**0.319**	6.95
P_{max}	< 0.001 (0.001)	0.962	−0.007 (0.009)	0.421	−0.005 (0.003)	0.096	0.024	**−0.055**	0.045	5.69
Breakpoint	0.001 (0.001)	0.406	−0.005 (0.008)	0.527	−0.003 (0.004)	0.544	**0.158**	0.007	0.101	2.85
Elasticity	**−0.002 (0.001)**	**0.004**	**−0.015 (0.008)**	**0.045**	−0.002 (0.004)	0.706	**−0.179**	**−0.179**	**−0.200**	0.30

B = slope; SE = standard error; 95% CI = 95% confidence interval; d.f. = degrees of freedom. Significant results are highlighted in bold type.

Table 4

Small study effects assessment

Demand index	Begg-Mazumdar test τ	Begg-Mazumdar test P	Egger's regression analysis Intercept (95% IC)	Egger's regression analysis P	Duval & Tweedie's trim-and-fill procedure $n_{trimmed}$	Duval & Tweedie's trim-and-fill procedure Difference
Alcohol use						
Intensity	−0.207	0.05	0.151 (−1.03, 1.33)	0.796	0	0
O_{max}	−0.129	0.253	**−1.187 (−2.12, −0.25)**	**0.014**	0	0
P_{max}	−0.188	0.161	−0.658 (−1.29, 0.12)	0.101	0	0
Breakpoint	−0.184	0.127	−0.592 (−1.38, 0.20)	0.137	0	0
Elasticity	0.111	0.349	−1.144 (−2.38, 0.97)	0.07	**9**	**−0.053**
Heavy drinking						
Intensity	−0.264	0.189	−0.826 (−2.89, 1.24)	0.401	0	0
O_{max}	−0.167	0.428	−1.415 (−3.01, 0.18)	0.076	0	0
P_{max}	0.109	0.64	−0.231 (−1.15, 0.69)	0.583	0	0
Breakpoint	−0.346	0.100	**−1.09 (−1.75,−0.43)**	**0.004**	0	0
Elasticity	−0.145	0.533	−0.73 (−3.05, 1.58)	0.492	0	0
Alcohol-related problems						
Intensity	0.048	0.756	0.601 (−1.69, 2.89)	0.590	0	0
O_{max}	0.117	0.446	−0.007 (−2.03, 2.02)	0.990	0	0
P_{max}	0.0	0.999	0.229 (−1.71,2.17)	0.802	0	0
Breakpoint	−0.255	0.14	0.143 (−1.45, 1.73)	0.851	0	0
Elasticity	−0.037	0.837	−0.937 (−2.24, 4.11)	0.539	0	0
Hazardous drinking						
Intensity	−0.165	0.284	1.294 (−0.26, 2.85)	0.098	**1**	**0.005**
O_{max}	−0.154	0.387	−0.598 (−2.61, 1.42)	0.537	0	0
P_{max}	−0.142	0.444	−0.221 (−1.39, 0.94)	0.69	0	0
Breakpoint	−0.17	0.325	−0.353 (−1.57, 0.87)	0.549	0	0
Elasticity	0.068	0.673	**−1.151 (−2.15, −0.15)**	**0.026**	0	0

τ = Kendall's tau; 95% CI = 95% confidence interval. Significant results are highlighted in bold type.