



Diagnostic performance of the Alcohol Use Disorders Identification Test (AUDIT) in detecting DSM-5 alcohol use disorders in the General population



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ABSTRACT

Objective: The Alcohol Use Disorders Identification Test (AUDIT) is an established screening questionnaire for the detection of at-risk drinking and possible alcohol use disorders (AUD) according to the Diagnostic and Statistical Manual of Mental Disorders – fourth edition (DSM-IV). But there are still no comparable results on the diagnostic performance regarding the new criteria for AUD in the Diagnostic and Statistical Manual of Mental Disorders – fifth edition (DSM-5), especially taking account of possible gender differences. We evaluated the performance of the full AUDIT and the consumption questions (AUDIT-C) in screening for DSM-5 AUD and at-risk drinking.

Method: Data from the study Transitions in Alcohol Consumption and Smoking (TACOS) is used to analyze the area under the receiver-operating characteristic curve, sensitivity, and specificity of the AUDIT and the AUDIT-C in the general population of northern Germany. DSM-5 AUD and at-risk drinking were assessed with the Munich-Composite Diagnostic Interview and used as gold standards.

Results: The best balance between sensitivity and specificity is achieved at a score of 5 for men and 4 for women. High severity, according to DSM-5, were associated with higher cut-offs.

Conclusions: Both AUDIT versions are accurate in the screening for DSM-5 AUD. Since the proposed cut-offs do not differ from the optimal screening cut-offs for DSM-IV disorders, current screening procedures should not face major changes.

1. Introduction

Screening questionnaires are frequently used to detect at-risk alcohol drinking or alcohol use disorders. The Alcohol Use Disorders Identification Test (AUDIT; Babor et al., 2001; Saunders et al., 1993) is an internationally well-established screening instrument, developed by the World Health Organization. The AUDIT has been used in primary care settings (Bischof et al., 2007; Rist et al., 2009; Shevlin and Smith, 2007) as well as the general population (Rumpf et al., 2002; von der Pahlen et al., 2008) to assess at-risk alcohol consumption and to screen for alcohol use disorders. Screening instruments are frequently used in general population studies because of their inexpensive and timesaving format. Several abbreviated versions of the AUDIT have been developed (de Meneses-Gaya et al., 2009). One of the most frequently used abbreviations is the AUDIT Alcohol Consumption Questions (AUDIT-C,

Bush et al., 1998). It consists of the first three items of the AUDIT.

The AUDIT has shown a high diagnostic accuracy for the screening of sub-clinical at-risk alcohol consumption in a number of different settings (Reinert and Allen, 2002; Selin, 2003), whereby at-risk drinking is defined as a quantity or pattern of alcohol consumption that increases the risk of future adverse health events (Reid et al., 1999). This is especially relevant for the implementation of early interventions (Babor et al., 2001; Senft et al., 1997). Although it is well established that the AUDIT is able to detect at-risk alcohol consumption and screen for alcohol abuse (AA) and alcohol dependence (AD) according to the criteria of the fourth edition of the Diagnostic and Statistical Manual of psychiatric disorders (DSM-IV, American Psychiatric Association, 2000; Rumpf et al., 2002) and despite the frequent use of both the AUDIT and the AUDIT-C in the general population (Dawson et al., 2012; Dybek et al., 2006; Selin, 2003), similar investigations evaluating the

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performance of the AUDIT in regard to the DSM-5 (American Psychiatric Association, 2013) are still scarce. Dawson et al. (2012) provided a preliminary analysis of the performance of the AUDIT-C in screening for DSM-5 alcohol use disorder compared to DSM-IV with a representative sample of US adults. They concluded that the performance of the AUDIT-C is comparable to or better for detecting DSM-5 alcohol use disorders (AUD) than AA and AD of DSM-IV. However, these results have not yet been replicated in the general population of other countries. Furthermore, Dawson et al. (2012) only used a modified version of the AUDIT-C and not the full scale of the screening questionnaire. Therefore, their results cannot be generalized on other populations or to the full AUDIT.

Several epidemiological studies found a group of cases below the threshold of AD (meeting 1 to 2 criteria) but without meeting any criteria of AA (e.g., Hasin and Paykin, 1999). These people would not be diagnosed with either AA or AD according to the DSM-IV despite possibly suffering from similarly strong problems of substance use as the group of AAs. While these “diagnostic orphans” would not be considered a diagnostic category in the DSM-IV, it has been classified in the group of mild AUD in the DSM-5, thus potentially including former subclinically at-risk drinker into clinically diagnosable AUD. With the potential shifts between classifications from DSM-IV to DSM-5, it is essential that alcohol screening instruments such as the AUDIT maintain their diagnostic accuracy at screening for AUD symptomatology according to the DSM-5 but also for subclinical at-risk alcohol consumption.

With the present study, we wanted: 1) to analyze and compare the performance of the AUDIT and the AUDIT-C in a general population sample; 2) to examine different cut-off points for both AUDIT and AUDIT-C in regards to their sensitivity and specificity in detecting at-risk drinking as well as AUD according to DSM-5 as compared to the classification of AA and AD according to DSM-IV; 3) to analyze gender-specific cut-off values regarding their sensitivity and specificity.

2. Methods

2.1. Sample

Data were taken from the study Transitions in Alcohol Consumption and Smoking (TACOS) which was conducted during 1996/97 in the general adult population of a northern German area (for more details on TACOS see Bischof et al., 2000; John et al., 2004; Meyer et al., 2000a,b; Rumpf et al., 2002). The sample of individuals born between 1932 and 1978 was randomly drawn from registration office files and potential participants were contacted via mail. Among the contacted individuals, 70.2% agreed to participate in the study. Data was collected during computer-assisted personal interviews. The interview was performed by 56 lay-interviewers who were trained in a one week course by WHO CIDI trainers and participated in individual weekly training sessions using feedback from previous interviews (Meyer et al., 2000a,b). For the current analyses, we included all participants who reported alcohol consumption during the last 12 months prior to the interview. Of the final sample ($n = 3623$), 53.5% were female, 43.4% had up to 9 years, 32.4% 10 to 11 years, and 22.7% received 12 or more years school education. Another 1.5% could not be classified in regards to their educational background. The age of the participants ranged from 18 to 64 years ($M = 41.3$, $SD = 12.8$).

2.2. Measures

The Munich Composite International Diagnostic Interview (M-CIDI; Wittchen et al., 1995) – a German version of the lifetime WHO CIDI (Robins et al., 1988) was used to assess AUD in the last 12 months according to DSM-IV and DSM-5 in a face-to-face interview. The M-CIDI had been shown to have excellent test-retest reliability for DSM-IV AUDs (Wittchen et al., 1998). The DSM-5 AUD criteria had mostly been

derived directly from the DSM-IV diagnostic module for AD. The craving criterion was assessed with the question: “Did you have a desire to drink alcohol that was so strong that you could not think about anything else?” and the criteria for social problems, repeated alcohol consumption in situations where this might lead to physical danger and failure to fulfil important obligations were derived from DSM-IV criteria of AA. The quantity-frequency questions of the M-CIDI were used to assess current alcohol consumption, i.e. alcohol consumption during the last 12 months. One standard drink was defined as containing 10.5 g of pure alcohol. At-risk drinking was defined as average daily consumption of ≥ 12 g for women and ≥ 24 g for men of pure alcohol during the last 12 months (Seitz et al., 2008).

A German translation of the AUDIT (Rumpf et al., 2001; Saunders et al., 1993) was administered as a paper-pencil-questionnaire to assess alcohol consumption. The full version of the AUDIT consists of 10 items, assessing the quantity and frequency of drinking (item 1–3) as well as problems caused by drinking (items 4–10). The total sum score ranges from 0 to 40 points. A score of 8 has been originally proposed as a cut-off to detect potentially hazardous alcohol consumption (Babor and Grant, 1989). However, various studies have proposed different cut-off scores, ranging from 5 to 11 (Babor et al., 2001; Dybek et al., 2006; Reinert and Allen, 2007), with 8 and 5 points as the most frequently used cut-offs. In Germany, a cut-off of ≥ 5 has shown the best sensitivity and specificity in a general population sample for the full-scale AUDIT (Dybek et al., 2006; Rumpf et al., 2002). Furthermore, some results have shown that the use of gender-specific cut-off scores, i.e. lower cut-offs for women, might be advisable (Reinert and Allen, 2007; Rumpf et al., 2002).

The AUDIT-C is an abbreviated form of the AUDIT consisting only of items 1 to 3, i.e. the items assessing quantity and frequency of alcohol consumption. The total score of the AUDIT-C ranges from 0 to 12 points. 4 or 5 points for females and males respectively was previously proposed as a cut-off score for detecting at-risk drinking and AUD with the AUDIT-C (Rumpf et al., 2002).

2.3. Data analysis

All analyses were calculated with Stata version 14.1 (StataCorp, 2015). First, we examined the alcohol use characteristics of our sample to examine potential changes due to the shifts of classification between DSM-IV and DSM-5. Gender-specific frequencies were compared using χ^2 -tests. The scores of AUDIT and AUDIT-C were compared between men and women using Welch’s t-tests to account for unequal variances. In a second step, to evaluate the screening performance of the AUDIT and AUDIT-C, Receiver Operating Characteristic (ROC) curves were calculated to explore the entire range of sensitivities and specificities at each possible cut-off value by plotting sensitivity at the y-axis vs (1 – specificity) at the x-axis. Sensitivity is the true positive rate, reflecting the proportion of individuals with a positive outcome (i.e. meeting the DSM-5 AUD criteria) who score below a given cut-off point. Specificity is the true negative rate and reflects the percentage of individuals with negative outcomes (i.e. not meeting the DSM-5 AUD criteria) scoring above a respective threshold of the screening questionnaire. While the choice of the ideal cut-off point might vary depending on the purpose of the screening, we chose the often used criterion of the best balance between sensitivity and specificity to determine the optimal cut-off points. Additionally, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and areas under the ROC curves (AUROC) were determined with their 95% confidence intervals. PPV is the probability that participants with a positive screening score at any given cut-off point meet the respective DSM-5 AUD criteria. NPV is the probability that participants with a negative screening score (i.e. below the cut-off) do not meet the respective criteria for the DSM-5 AUD diagnosis. AUROCs are calculated to provide a global measure of the diagnostic accuracy and they should be close to 1.0 and at least .70 (Rice and Harris, 2005) to indicate a good overall performance of the screening

Table 1
Comparison of diagnostic groups across DSM classification systems.

Diagnostic group	DSM-5		
	Mild AUD (n = 146)	Moderate AUD (n = 24)	Severe AUD (n = 32)
At-risk drinking	44.5%	0%	0%
DSM-IV			
Alcohol abuse (n = 84)	45.2%	16.7%	0%
Alcohol dependence (n = 67)	10.3%	83.3%	100%

questionnaire. χ^2 -tests were used for all comparisons of AUROCs. The analyses were first conducted for the overall sample, followed by gender-specific calculations of sensitivity, specificity, PPV, NPV, and AUROC in order to determine gender-specific cut-off values. Since the number of cases for severe AUD separated for men and women were too small to be used for reliable estimations, for gender-specific analyzes, we combined the cases of moderate and severe AUD into one category.

3. Results

3.1. Alcohol use characteristics

Of the overall sample, $n = 445$ (12.3%) fulfilled the criteria for at-risk drinking without meeting the criteria of AUD, $n = 206$ (5.7%) fulfilled at least two of the DSM-5 AUD criteria in the last 12 months (of which 12 could be identified as former “diagnostic orphans”), $n = 58$ (1.6%) fulfilled at least four, and $n = 32$ (0.9%) fulfilled six or more of the DSM-5 AUD criteria in the last 12 months according to M-CIDI. Of the overall sample, 84.4% did not show any of the DSM-5 symptoms of AUD. Table 1 displays the distributions between at-risk drinking, AA, AD, mild, moderate, and severe AUD. This illustrates the shifts in classification from DSM-IV to DSM-5 and the addition of new cases into the DSM-5 AUD diagnosis, which were formerly classified as at-risk drinking or AA while the majority of moderate AUD cases were classified as AD according to DSM-IV. However, there are still overlaps with AA. The cases of severe AUD stem solely from the DSM-IV AD classifications.

All means and standard deviations are displayed in Table 2. Significantly more men than women scored positively for at-risk drinking ($p = .001$) indicating a higher prevalence for risky alcohol consumption without an AUD diagnosis. These differences are also present for all three severities of AUD (mild $p < .001$; moderate: $p < .001$; severe: $p = .02$). Furthermore, women reported significantly lower alcohol consumption than men on the AUDIT ($p < .001$) and AUDIT-C ($p < .001$).

Table 2
Means across diagnostic groups and alcohol consumption.

	Overall		Men		Women	
	M (SD)	95% CI	M (SD)	95% CI	M (SD)	95% CI
DSM-5 symptoms	0.35 (1.15)	0.32-0.39	0.54 (1.41)	0.48-0.61	0.16 (0.73)	0.12-0.19
DSM-IV symptoms	0.26 (0.83)	0.23-0.28	0.38 (1.00)	0.33-0.43	0.13 (0.58)	0.10-0.15
At-risk drinking	.12 (.33)	.11-.13	.14 (.35)	.12-.16	.10 (.31)	.09-.12
Any criterion	.18 (.38)	.17-.19	.23 (.42)	.21-.24	.13 (.34)	.12-.15
AUDIT	3.61 (3.08)	3.10-3.21	4.47 (3.62)	4.30-4.63	2.71 (2.05)	2.62-2.81
AUDIT-C	3.15 (1.81)	3.10-3.21	3.77 (1.91)	3.69-3.86	2.51 (1.43)	2.45-2.58

Note. DSM-5 symptoms: mean number of symptoms for classification of AUD according to DSM-5; DSM-IV symptoms: mean number of symptoms for classification of AA and AD according to DSM-IV; At-risk drinking: prevalence of at-risk drinking excluding DSM-5 or DSM-IV diagnoses; any criterion: prevalence of meeting any of the diagnostic criteria including at-risk drinking; AUDIT: mean AUDIT score; AUDIT-C: mean AUDIT-C score; SD = standard deviation; 95% CI = 95% confidence interval.

Table 3
Performance of AUDIT and AUDIT-C for different diagnostic.

Overall				
Diagnostic group	AUDIT		AUDIT-C	
	AUROC	95% CI	AUROC	95% CI
At-risk drinking	.82	.80-.83	.83	.82-.85
Mild AUD	.83	.80-.86	.79	.76-.83
Moderate and severe AUD	.91	.86-.96	.84	.78-.91
Any criterion	.85	.84-.87	.85	.83-.87
Men				
Diagnostic group	AUDIT		AUDIT-C	
	AUROC	95% CI	AUROC	95% CI
At-risk drinking	.78	.76-.81	.81	.79-.83
Mild AUD	.78	.74-.82	.74	.69-.79
Moderate and severe AUD	.87	.80-.95	.82	.73-.90
Any criterion	.82	.80-.84	.82	.80-.84
Women				
Diagnostic group	AUDIT		AUDIT-C	
	AUROC	95% CI	AUROC	95% CI
At-risk drinking	.86	.84-.89	.87	.85-.89
Mild AUD	.88	.82-.93	.84	.78-.89
Moderate and severe AUD	.98	.95-1.0	.90	.81-.98
Any criterion	.88	.86-.90	.88	.86-.90

Notes. AUD = alcohol use disorder; AUROC = area under the receiver operating characteristic curve; 95% CI = 95% confidence interval.

3.2. Performance of the AUDIT and AUDIT-C in screening for AUD

Overall sample: The AUROCs (see Table 3) were highest for moderate and severe AUD, both for AUDIT and AUDIT-C. Only the area for at-risk drinking was below .90 for both screening instruments. Nevertheless, it was still high enough to indicate a good performance of the tests to detect at-risk alcohol consumption. For the AUDIT-C, the AUROC for at-risk drinking was significantly higher than the AUROC of the full version of the AUDIT ($p < .001$). However, the AUDIT showed higher AUROCs than the AUDIT-C for mild ($p < .001$), moderate ($p < .001$) and severe AUD ($p = .02$), indicating a better performance of the full AUDIT for the detection of clinically relevant AUDs.

To compare the performance of the AUDIT and AUDIT-C for detecting AUD in accordance to the DSM-5 with the previous classifications of current AA and current AD according to DSM-IV, we plotted additional ROC curves using the DSM-IV criteria as gold standard (see Supplemental Table A). The data for the full scale of the AUDIT revealed higher AUROCs than the AUDIT-C (AA: $p < .001$; AD: $p < .001$). In order to find optimal cut-off points for at-risk drinking and meeting the criteria for DSM-5 AUD, the best balance between sensitivities and specificities was sought. The best balance between sensitivities and specificities for the detection of mild AUD with the full-scale

Table 4
Sensitivities and specificities of AUDIT and AUDIT-C for the detection of diagnostic groups according to DSM-5 on different cut-off scores for men.

Men								
Cut-off	Mild AUD (n = 156)				Moderate and severe AUD (n = 45)			
	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)
AUDIT								
3	.90 (.85-.94)	.26 (.24-.28)	.10 (.09-.12)	.96 (.95-.98)	.91 (.79-.97)	.25 (.23-.27)	.03 (.02-.04)	.99 (.98-1.0)
4	.84 (.78-.90)	.46 (.44-.48)	.12 (.11-.15)	.97 (.96-.98)	.91 (.79-.97)	.44 (.42-.47)	.03 (.03-.05)	.99 (.99-1.0)
5	.73 (.66-.80)	.67 (.65-.69)	.17 (.14-.20)	.96 (.95-.97)	.86 (.73-.95)	.64 (.63-.67)	.05 (.04-.08)	.99 (.99-1.0)
6	.64 (.56-.72)	.82 (.81-.84)	.25 (.21-.30)	.96 (.95-.97)	.84 (.70-.93)	.80 (.78-.82)	.09 (.07-.13)	.99 (.99-1.0)
7	.53 (.46-.62)	.93 (.92-.94)	.31 (.26-.37)	.95 (.94-.96)	.77 (.63-.89)	.87 (.85-.89)	.13 (.09-.18)	.99 (.99-1.0)
8	.47 (.39-.56)	.92 (.91-.94)	.37 (.31-.45)	.95 (.94-.96)	.73 (.58-.85)	.90 (.89-.92)	.16 (.12-.23)	.99 (.99-1.0)
AUDIT-C								
3	.87 (.82-.92)	.27 (.25-.29)	.10 (.08-.12)	.96 (.94-.98)	.88 (.76-.96)	.26 (.24-.28)	.02 (.02-.04)	.98 (.97-1.0)
4	.79 (.72-.85)	.48 (.46-.51)	.12 (.10-.15)	.96 (.95-.97)	.84 (.70-.93)	.46 (.44-.49)	.03 (.03-.05)	.99 (.98-1.0)
5	.63 (.55-.71)	.72 (.70-.74)	.17 (.14-.21)	.95 (.94-.97)	.77 (.63-.89)	.70 (.68-.72)	.06 (.04-.08)	.99 (.98-.99)
6	.51 (.43-.59)	.89 (.87-.90)	.29 (.24-.35)	.95 (.94-.96)	.73 (.58-.85)	.87 (.85-.88)	.12 (.09-.17)	.99 (.99-1.0)

Notes. Sens. = sensitivity; Spec. = specificity; PPV = positive predictive value; NPV = negative predictive value; AUD = alcohol use disorder as classified by DSM-5; 95% CI = 95% confidence interval.

AUDIT was found at a cut-off of 5, while the detection of moderate and severe AUD seemed to require a cut-off score of ≥ 6 . The AUDIT-C showed the optimal cut-off at a score of ≥ 4 for mild AUD and at ≥ 5 for moderate and severe AUD.

For both AUDIT and AUDIT-C, the sensitivities and specificities for AA and AD are comparable to mild and moderate AUD as classified in DSM-5, respectively (see Supplemental Tables B to D).

Gender-specific results: We observed significant differences in the performance of the AUDIT across male and female participants. AUROCs were higher for women than for men for the full-scale of the AUDIT as well as for the AUDIT-C. The AUROC (see Table 3) differed significantly between men and women for at-risk drinking ($p < .001$), mild ($p = .01$), and moderate AUD ($p = .01$). But there was no difference for severe AUD ($p = .24$). A comparison of the AUROC for the AUDIT-C revealed differences only for at-risk drinking ($p < .001$) and mild AUD ($p = .01$). There was no difference for moderate ($p = .19$) and severe AUD ($p = .71$) between men and women.

Sensitivity and specificity for men are shown in Table 4 and 5 for the detection of DSM-5 AUD and at-risk drinking. For the full scale of the AUDIT, the best balance between sensitivities and specificities for men was achieved at a cut-off point of ≥ 5 for the detection of at-risk drinking and mild AUD and at a cut-off point of ≥ 6 for the detection of moderate and severe AUD. A cut-off of ≥ 5 is proposed for the AUDIT-C. For women, the best balance between sensitivities and specificities for the full-scale AUDIT was reached at a cut-off point of ≥ 4 for at-risk

drinking and mild AUD and at a cut-off of ≥ 5 for moderate and severe AUD. The AUDIT-C showed the best balance at a score of ≥ 4 for women for all diagnostic groups. All sensitivities and specificities for female participants are displayed in Table 6 and 7.

4. Discussion

We examined the diagnostic performance of the AUDIT and AUDIT-C in detecting DSM-5 AUDs in a general adult population sample in regards to the AUROCs as well as sensitivity and specificity at different cut-off scores. The high AUROC for both versions of the alcohol screening questionnaire indicates a good and accurate performance in the general population. This supports the diagnostic proficiency of the AUDIT in the detection of DSM-5 AUDs which has previously only been shown in college samples from the United States (Hagman, 2015, 2016).

The current results further emphasize the impact of the observed population for the interpretation of findings on the psychometric properties of the AUDIT. Samples from different populations (i.e. other assessment settings or different countries) may very likely find different distributions of AUDs as classified by DSM-5, as indicated by results showing variability in AUD prevalence (Rehm et al., 2005) and differences in alcohol consumption across several countries in Europe (Bosque-Prous et al., 2014). Further research on moderate and severe AUD as distinct categories might be crucial, considering that our results

Table 5
Sensitivities and specificities of AUDIT and AUDIT-C for the detection of at-risk drinking and any criterion on different cut-off scores for men.

Men								
Cut-off	At-risk drinking (n = 259)				Any criterion (n = 415)			
	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)
AUDIT								
3	.98 (.97-1.0)	.44 (.42-.46)	.19 (.18-.21)	.99 (.98-.99)	.95 (.93-.97)	.30 (.28-.33)	.28 (.26-.31)	.96 (.94-.98)
4	.95 (.92-.98)	.49 (.47-.52)	.23 (.21-.27)	.98 (.97-.99)	.91 (.88-.94)	.53 (.51-.56)	.36 (.33-.39)	.95 (.94-.97)
5	.76 (.71-.81)	.70 (.68-.72)	.29 (.26-.33)	.94 (.93-.96)	.75 (.71-.79)	.75 (.73-.77)	.46 (.43-.51)	.91 (.90-.93)
6	.47 (.41-.54)	.82 (.81-.85)	.31 (.27-.36)	.90 (.89-.92)	.54 (.49-.59)	.88 (.86-.90)	.56 (.51-.61)	.86 (.85-.88)
7	.30 (.25-.36)	.88 (.86-.90)	.29 (.24-.35)	.88 (.87-.90)	.39 (.34-.44)	.92 (.91-.94)	.60 (.55-.67)	.84 (.82-.86)
8	.21 (.16-.27)	.91 (.90-.92)	.28 (.22-.35)	.87 (.86-.89)	.31 (.27-.36)	.95 (.94-.96)	.65 (.59-.72)	.82 (.81-.84)
AUDIT-C								
3	.98 (.97-1.0)	.29 (.27-.32)	.18 (.17-.21)	.99 (.98-1.0)	.94 (.92-.97)	.31 (.29-.34)	.28 (.26-.31)	.95 (.93-.97)
4	.95 (.92-.98)	.52 (.50-.55)	.24 (.22-.28)	.98 (.97-.99)	.89 (.86-.92)	.56 (.54-.59)	.37 (.34-.40)	.94 (.93-.96)
5	.73 (.67-.78)	.76 (.74-.78)	.33 (.29-.37)	.94 (.93-.96)	.69 (.65-.74)	.80 (.78-.82)	.50 (.46-.55)	.90 (.88-.92)
6	.40 (.34-.46)	.89 (.88-.91)	.38 (.32-.44)	.90 (.89-.92)	.44 (.39-.49)	.94 (.92-.95)	.67 (.61-.73)	.85 (.83-.87)

Notes. Sens. = sensitivity; Spec. = specificity; PPV = positive predictive value; NPV = negative predictive value; 95% CI = 95% confidence interval.

Table 6
Sensitivities and specificities of AUDIT and AUDIT-C for the detection of diagnostic groups according to DSM-5 different cut-off scores for women.

Women		Mild AUD (n = 50)				Moderate and severe AUD (n = 13)			
Cut-off	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)	
AUDIT									
3	.90 (.78-.97)	.54 (.52-.57)	.05 (.04-.07)	.99 (.98-1.0)	1.0 (.75-1.0)	.54 (.52-.56)	.01 (.01-.03)	1.0 (.99-1.0)	
4	.82 (.69-.91)	.78 (.76-.80)	.09 (.07-.13)	.99 (.98-1.0)	1.0 (.75-1.0)	.77 (.75-.79)	.03 (.02-.05)	1.0 (.99-1.0)	
5	.68 (.53-.80)	.91 (.90-.93)	.19 (.13-.25)	.99 (.98-.99)	.92 (.64-1.0)	.90 (.89-.92)	.06 (.03-.11)	.99 (.98-1.0)	
6	.56 (.41-.70)	.96 (.95-.97)	.30 (.21-.40)	.98 (.98-.99)	.84 (.55-.98)	.95 (.94-.96)	.11 (.06-.20)	.99 (.99-1.0)	
7	.48 (.34-.63)	.97 (.97-.98)	.36 (.25-.49)	.98 (.98-.99)	.84 (.55-.98)	.96 (.96-.98)	.16 (.09-.28)	.99 (.99-1.0)	
8	.40 (.26-.55)	.98 (.97-.99)	.40 (.26-.55)	.98 (.97-.99)	.76 (.46-.95)	.97 (.97-.98)	.20 (.10-.34)	.99 (.99-1.0)	
AUDIT-C									
3	.88 (.76-.95)	.55 (.53-.58)	.05 (.04-.07)	.99 (.99-1.0)	.92 (.64-1.0)	.54 (.52-.57)	.01 (.01-.03)	.99 (.99-1.0)	
4	.76 (.61-.87)	.79 (.77-.81)	.09 (.07-.13)	.99 (.98-1.0)	.92 (.64-1.0)	.78 (.76-.80)	.03 (.02-.05)	.99 (.99-1.0)	
5	.50 (.35-.64)	.93 (.92-.94)	.17 (.12-.25)	.98 (.98-.99)	.61 (.32-.86)	.92 (.91-.94)	.05 (.02-.11)	.99 (.99-1.0)	
6	.28 (.16-.43)	.98 (.97-.99)	.28 (.16-.42)	.98 (.07-.99)	.46 (.19-.75)	.98 (.97-.98)	.12 (.04-.24)	1.0 (.99-1.0)	

Notes. Sens. = sensitivity; Spec. = specificity; PPV = positive predictive value; NPV = negative predictive value; AUD = alcohol use disorder as classified by DSM-5; 95% CI = 95% confidence interval.

Table 7
Sensitivities and specificities of AUDIT and AUDIT-C for the detection of at-risk drinking and any criterion on different cut-off scores for women.

Women		At-risk drinking (n = 186)				Any criterion (n = 236)			
Cut-off	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)	
AUDIT									
3	.95 (.91-.98)	.59 (.57-.62)	.21 (.19-.24)	.99 (.98-.99)	.94 (.90-.97)	.60 (.58-.63)	.26 (.24-.30)	.98 (.98-.99)	
4	.76 (.70-.83)	.82 (.81-.85)	.34 (.30-.39)	.98 (.97-.99)	.78 (.72-.83)	.84 (.83-.87)	.44 (.39-.49)	.96 (.95-.97)	
5	.41 (.35-.49)	.93 (.92-.95)	.43 (.36-.51)	.93 (.92-.94)	.47 (.41-.54)	.95 (.94-.97)	.62 (.55-.70)	.92 (.91-.93)	
6	.21 (.15-.27)	.96 (.96-.97)	.41 (.32-.53)	.91 (.90-.93)	.28 (.23-.35)	.98 (.98-.99)	.72 (.62-.81)	.90 (.88-.91)	
7	.15 (.11-.22)	.97 (.97-.98)	.43 (.32-.57)	.90 (.89-.92)	.22 (.17-.28)	.99 (.99-1.0)	.80 (.69-.89)	.89 (.88-.91)	
8	.12 (.08-.19)	.98 (.98-.99)	.48 (.34-.63)	.90 (.89-.92)	.18 (.14-.24)	.99 (.99-1.0)	.88 (.76-.95)	.88 (.87-.90)	
AUDIT-C									
3	.95 (.91-.98)	.60 (.58-.63)	.21 (.19-.25)	.99 (.98-1.0)	.93 (.90-.96)	.61 (.59-.64)	.27 (.24-.30)	.98 (.97-.99)	
4	.76 (.70-.82)	.84 (.82-.86)	.36 (.31-.41)	.96 (.96-.98)	.76 (.70-.81)	.86 (.84-.88)	.45 (.41-.51)	.96 (.95-.97)	
5	.38 (.32-.46)	.95 (.95-.97)	.51 (.43-.60)	.93 (.92-.94)	.41 (.35-.48)	.97 (.96-.98)	.69 (.61-.77)	.91 (.90-.93)	
6	.14 (.09-.20)	.98 (.98-.99)	.51 (.37-.65)	.91 (.89-.92)	.17 (.12-.22)	.99 (.99-1.0)	.78 (.65-.89)	.89 (.87-.90)	

Notes. Sens. = sensitivity; Spec. = specificity; PPV = positive predictive value; NPV = negative predictive value; 95% CI = 95% confidence interval.

suggest that higher cut-off values should be used for the AUDIT to screen for at least moderate severity in AUD cases. In contrast, for the AUDIT-C a cut-off value of $\geq 4/5$ (for women and men, respectively) was adequate for all severities of DSM-5 AUDs (Tables 4–7). This corresponds with previous recommendations on the cut-off for the AUDIT-C in German samples (Rumpf et al., 2002, 2013).

In line with previous findings, we found lower mean scores in women for both AUDIT and AUDIT-C (e.g., Knibbe et al., 2006; Moehring et al., 2018), larger AUROC values, and lower sensitivities (e.g., Rumpf et al., 2002). Our results further support the use of lower cut-off scores for women for the full scale of the AUDIT as well as the AUDIT-C. The higher PPVs for men could be due to the higher prevalence for any criterion (i.e. at-risk drinking, AUD) as compared to women in the tested population.

Furthermore, the proposed cut-off values for the AUDIT might vary, depending on the intended purpose of the alcohol screening questionnaire (Conigrave et al., 1995). Screening questionnaires are usually used with the purpose of detecting as much true positives as possible, for example for recruitment purposes in intervention approaches, thus, the sensitivity should be maximized and the NPV is high, allowing for a high confidence that a negative screening result is true. For this purpose, even lower cut-offs than the proposed score of 4/5 might be preferred. However, the AUDIT is often used for screening of specific diagnostic classifications (Babor et al., 2001; Dawson et al., 2005; de Meneses-Gaya et al., 2009; Rubinsky et al., 2013), which would require

high specificity, especially with increasing severity of AUD. For this purpose, the PPV at the balanced cut-off scores is too low to be considered accurate, since many of the positive screenings would be false positives. Thus, higher cut-offs should be chosen, if the aim of the screening is primarily to avoid false positives. Higher cut-offs, at least for men, might also be chosen if the maximum sum of sensitivity and specificity was chosen as a judgment criterion for the optimal cut-off point, e.g. either 6 or 7 for mild AUD. However, this would lead to rather low sensitivities. Our results suggest a score of $\geq 4/5$ as a cut-off for at-risk drinking and mild AUD and a score of $\geq 5/6$ for the screening of moderate and severe AUD, for women and men respectively in a general population sample (see Tables 4–7).

Both the AUDIT and the AUDIT-C showed an adequate screening performance for subclinical at-risk drinking and DSM-5 disorders (Table 3). The AUDIT performed significantly better for the detection of clinically relevant AUDs (i.e. mild, moderate and severe AUD), as indicated by the higher AUROC values. These differences grew more distinct with increasing severity of the disorder. Similarly, the full-scale of the AUDIT showed significantly higher AUROCs for AA and AD, as classified by DSM-IV, compared to at-risk drinking. This suggests that the full scale of the AUDIT should preferably be used if the goal is to detect at least mild AUD. However, for subclinical at-risk drinking, the AUDIT-C is equally adequate and proficient as a screening questionnaire. Therefore, future research could profit from either carefully choosing between AUDIT and AUDIT-C depending on the targeted

severity (i.e. subclinical or clinically relevant alcohol consumption), or an adaptive screening procedure might be used by presenting the AUDIT-C to all participants and only those who reach the cut-off of at least 4/5 points (for women and men, respectively) are additionally presented with items 4-10. This adaptive procedure might be best applicable with an automatized computerized screening (e.g. on handheld tablet computers or smartphones), since the fulfillment for the administration of the full AUDIT scale could be implemented in the program.

Some limitations have to be considered for the interpretation of the current results. First, the prevalence rates of AUDs were quite low in our sample. Thus, we did not have enough cases of severe AUD (in particular for the female participants) to analyze this subgroup separately by gender. Therefore, we had to analyze a combined category including moderate and severe AUD. Second, the data used for the presented analyses are about 20 years old. This might influence the current results, since slight decreases in the average alcohol consumption in Germany have been observed over the last 40 years (John & Hanke, 2018). However, there are almost no substantial changes in the alcohol consumption in absolute terms of alcohol consumption and Germany is still among the ten countries with the highest per capita consumption (World Health Organization, 2018). Furthermore, we could not provide gender-specific analyses for the detection of severe AUD separate from moderate AUD. However, the current results indicate that a higher cut-off score might be necessary for the full scale of the AUDIT with increasing severity of AUD for both men and women, as indicated by the results of the overall sample. It should be noted, that the modes of presentation differed for the AUDIT and the M-CIDI. While the M-CIDI is an oral interview (for more information on interviewer training, quality assurance and posterior editing see Meyer et al., 2000a,b), the AUDIT was presented as a self-administered paper-pencil questionnaire. Self-report instruments are known to be impacted by recall or social biases. Nevertheless, the AUDIT has been shown to be a psychometrically sound questionnaire (Bradley et al., 2007; Moehring et al., 2018).

5. Conclusions

The findings suggest that both the full-scale version of the AUDIT and the abbreviated version AUDIT-C are adequate and valid screening questionnaires for the detection of DSM-5 AUD in the general population. Gender-specific cut-off values (4/5, and 5/6 for the full-scale and 4/5 for the AUDIT-C, for women and men, respectively) are desirable in order to improve the accuracy of the screening. Furthermore, the cut-off values for the AUDIT might have to be adjusted depending on the severity of the AUD to be detected. The screening performance for DSM-5 AUDs is similar to the detection of DSM-IV alcohol abuse and dependence and might be even slightly better as indicated by the higher AUROCs. It should be noted, that the AUDIT has been developed for the detection of at-risk drinking and not primarily to detect AUDs. Accordingly, both versions of the AUDIT are even more effective screening tools for at-risk alcohol consumption.

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Contributors

AM, CM, HJR, GB, UH, and UJ were responsible for the conceptualization of the current work. The respective data acquisition and in-field investigation as well as the data preparation were done by GB, CM, HJR, UH and AM. The data of the current work was analyzed and interpreted by AM. The manuscript was drafted by AM and critically reviewed by all authors (AM, CM, UJ, HJR, GB, UH). All authors have approved the final manuscript and will hold themselves jointly and individually responsible for its content.

Declaration of Competing Interest

No conflict declared

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.drugalcdep.2019.06.032>.

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