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RESEARCH REPORT

ADDICTION

Predictive validity of Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) for register-based alcohol-attributable events among general-population men and women of different ages

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Abstract

Background and aims: Originally developed for clinical screening for hazardous alcohol use, the Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) is also widely used in epidemiological research and monitoring. However, its cutoff values may not suit all purposes, and evidence on its predictive validity is limited. We examined how AUDIT-C scores relate to subsequent register-based alcohol-attributable events across age and sex and identified optimal thresholds for predicting these outcomes.

Design: Five general population surveys conducted in 2011–2017, linked to nationwide registers with follow-up until the end of 2023 (total follow-up 879 964 person-years).

Setting: Nationwide, Finland.

Participants: Adults aged ≥20 years (n = 103 567).

Measurements: AUDIT-C to assess exposure. Outcome: incident alcohol-attributable events in any of the registers capturing care, deaths and prescription medicines (n = 1444).

Findings: The hazard of register-based alcohol-attributable events increased approximately exponentially with increasing AUDIT-C score. It rose more strongly among women than men [hazard ratio (HR) = 1.61, 95% confidence interval (CI) = 1.55–1.67 for women; HR = 1.45, 95% CI = 1.40–1.49 for men; $P < 0.001$ for the sex × AUDIT-C interaction]. The risk of alcohol-attributable events was statistically significantly raised at 2 points among women and 3 points among men with 1 point as a reference level. The suggested optimal cutoff values were 2 points for women aged ≥80, 3 points for women aged 65–79 and men aged ≥80, 5 points for women aged 20–64 and men aged 65–79 and 6 points for men aged 20–64.

Conclusions: Using Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) scores, optimal cutoff values for predicting alcohol-attributable harm may differ by age

The authors, most of whom are not native English speakers, used ChatGPT to check the language and improve the clarity of the manuscript. All scientific content was prepared by the authors.

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and sex, with lower cutoffs for older individuals and women. The ≥65 age group appears to be heterogeneous with regard to vulnerability to alcohol-attributable harm, which should be considered when establishing cutoffs or guidelines for alcohol use.

KEYWORDS
age differences, alcohol-attributable harm, AUDIT-C, cut-offs, predictive validity, registers

INTRODUCTION

Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) is a three-item screening instrument for hazardous alcohol use covering drinking frequency, typical quantity per occasion and the frequency of drinking six or more drinks on one drinking occasion [1]. AUDIT-C items are the first three of the 10-item AUDIT developed by the World Health Organization (WHO) [2]. WHO recommends the AUDIT for screening and brief interventions in primary care [2]. The shorter AUDIT-C is favoured for the same purpose particularly in busy clinical settings [3].

The validity of both AUDIT and AUDIT-C in identifying hazardous drinking is well established, with AUDIT-C performing nearly as well as the full AUDIT [3]. The AUDIT was originally developed and validated against at-risk alcohol use defined as ≥40 g/day for men and ≥20 g/day for women in a multi-country study (Saunders and Aasland [4], cited in Higgins-Biddle and Babor [5]), but also alternative definitions have been applied [3]. For instance, Finnish cut-offs were based on weekly limits of ≥16 and >10 drinks (27 and 17 g/day) for 25 to 64-year-old men and women, respectively [6], and ≥8 drinks per week (14 g/day) for those ≥65 years old [7]. More recent studies from the United States (US) and Germany have instead used standardized diagnostic criteria for alcohol abuse and dependence as the reference standard when assessing AUDIT-C validity [1,8,9]. This shift from volume-based to diagnosis-based reference standard has been criticized for distorting the original purpose of the instrument and rendering its validity for clinical use questionable [5].

AUDIT-C is increasingly applied beyond its original purpose of face-to-face health care screening, for example, as a consumption measure in online screening and intervention applications [10], epidemiological studies [11] and monitoring surveys [12]. Although this expansion highlights the demand for a brief measure of alcohol consumption, changes in purpose necessitate reconsideration of reference standards and optimal cut-offs. In face-to-face health-care screening, high sensitivity is prioritized over specificity to minimize false negatives, as the only anticipated drawback of false positives is an unnecessary discussion. In contrast, in contexts such as regional monitoring, the aim may be to track alcohol-related harm using fixed survey variables without possibility of follow-up questions, and excessive sensitivity can be problematic. For example, in Finland, AUDIT cut-points developed for screening classified 47% of alcohol users among men ≥65 years old as excessive drinkers in 2022 [13]. In such cases, higher specificity and cut-offs could be preferred.

Overall, international research on screening instrument performance has extensively covered sex-specific cut-offs with less evidence on age-specific variation [3]. Although studies among young [14] and older populations [15] exist, few allow age group comparisons. Low specificity and poor performance of both AUDIT versions among older adults has been recognized beyond Finland [3]. Adults 65 years and older are often treated as a single group despite substantial heterogeneity in health status, comorbidity, functional capacity and medication use [16,17]. Applying a single cut-off to this age range is, therefore, likely to produce values that are too low for younger older adults, while simultaneously risking under-identification of risks among the oldest.

Even in healthcare screening, the ultimate goal is to prevent harm. However, longitudinal studies examining the predictive validity of the AUDITs for concrete harms remain scarce, possibly because of lack of large-scale, high-quality data. Existing longitudinal studies have mostly focused on (select) healthcare populations, and examined associations between AUDIT(-C) scores—using various cut-offs—and outcomes such as all-cause mortality (see Kuitunen-Paul and Roerecke [18] for a review) or hospitalizations for any cause [19] or specific conditions [20–22]. In a notable exception, Brummer *et al*. [11] linked a nationwide Danish survey with register-based health records and found that an AUDIT-C cut-off of six best predicted subsequent hospital admissions for alcohol-attributable conditions; however, analyses were not stratified by age or sex.

In Finland, nationwide health surveys conducted by the Finnish Institute for Health and Welfare (THL) during the 2010s and 2020s have included the AUDIT-C and have been linked with comprehensive health registers. This provides a unique opportunity to assess the predictive validity of AUDIT-C for alcohol-attributable harm in the general population. Such evidence is relevant both for clinical decision-making and for applications that extend the use of AUDIT-C beyond clinical settings. Rather than proposing new cut-offs, this study contributes evidence to inform such applications. Specifically, our aims are:

1. to examine the association between AUDIT-C score and incident alcohol-attributable healthcare events in the general population, overall and by age group (20–64, 65–79, and ≥80) and sex; and
2. to assess the sensitivity and specificity of alternative AUDIT-C cut-offs for predicting alcohol-attributable events, using receiver operating characteristic (ROC) analysis to suggest optimal cut-offs for this outcome across population subgroups.

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METHODS

Data

This study used data from five nationwide cross-sectional general-population health surveys representative of the adult population in Finland: the Health 2011 Survey [23], the Regional Health and Wellbeing Studies 2013, 2014 and 2015 [24] and the FinHealth Study 2017 [25]. The first and last were health examination surveys, the others postal health questionnaires. Analyses were restricted to participants ≥20 years old, available for all surveys. The numbers of participants were 6739, 49 865, 19 580, 20 338 and 7045 in the five surveys (103 567 in total). Response rates and numbers of participants after each data exclusion step are presented in Figure S1.

Survey data were linked at the individual-level to the Care Register for Health Care, the Cause of Death Register and the Prescription Register of the Social Insurance Institution of Finland using personal identity codes. This enables follow-up of hospitalizations, mortality and prescription medicine purchases. Register follow-up was available until the end of 2023 for all surveys. Maximum follow-up ranged from 6.9 (FinHealth 2017) to 12.4 years (Health 2011). Data from the Care Register for Health Care were available from 1969 onward for all surveys, and data from the Prescription Register from 1995 for Health 2011 and FinHealth 2017 and from 2010 for the Regional Health and Wellbeing Studies.

Ethical approval for the health examination surveys and register linkages was obtained from the Hospital District of Helsinki and Uusimaa Regional Committee on Medical Research Ethics. Written informed consent was obtained from all participants. For the questionnaire surveys and their register linkages, ethical approval was granted by the THL working group on research ethics. Participants were informed about the study, including register linkages, and completion of the questionnaire was considered consent. Permission to use the data can be applied for through Findata (https://findata.fi/en/).

Measures

AUDIT-C information was collected using a questionnaire in all five surveys. The AUDIT-C items assessed (1) frequency of alcohol use (scored 0 = never to 4 = four or more times per week); (2) typical quantity consumed on drinking days (0 = 1–2 drinks to 4 = 10 or more drinks; a unit was defined as 12 g of alcohol and explained to respondents); and (3) frequency of consuming six or more drinks per occasion (0 = never to 4 = daily or almost daily). The total score ranged from 0 to 12. Participants reporting no current alcohol use were not asked the remaining items and were assigned a score of zero (23.8%). Participants with missing AUDIT-C responses for other reasons were excluded (n = 5154; 5.0%).

The outcome was incident alcohol-attributable events after baseline, identified through register linkage. Participants were classified as having experienced alcohol-attributable events if they had wholly alcohol-attributable International Classification of Diseases (ICD)-codes recorded in the Care Register for Health Care (principal or secondary diagnosis) or in the Cause of Death Register (underlying or contributory cause) or a record in the Prescription Register indicating purchases of medications used to treat alcohol dependence. Wholly alcohol-attributable ICD-10 codes were defined using an established list of such causes (see the detailed list in Supporting information). Events with diagnoses that are only partially attributable to alcohol (e.g. cancers) were not classified as alcohol-attributable. The Care Register includes hospitalizations and outpatient visits in specialized health care, as well as emergency department visits (but not primary care visits). Individuals with alcohol-attributable register entries before baseline were excluded, yielding an analytical sample of 95 477 participants. Follow-up time was censored at the end of the follow-up (31 December 2023) or at death from other than alcohol-attributable causes.

Covariates included age and sex, obtained for all participants from the population register.

Statistical methods

Cox proportional hazards models were used to estimate hazard ratios (HRs) with 95% CIs for the association between AUDIT-C score and incident alcohol-attributable events. AUDIT-C was modelled both as a continuous and a categorical variable. The sampling design was taken into account, and survey weights were used to adjust for missing data and unequal sampling probabilities, yielding population-representative estimates. The proportional hazards assumption was assessed using Schoenfeld residuals. Rao-Scott likelihood ratio test was used as an overall test for interaction terms.

To assess heterogeneity across surveys, an interaction between AUDIT-C and survey year was included in the model. Survey year was specified both as a continuous and a categorical variable, and no evidence of interaction was observed.

Analyses were conducted for the full sample and stratified by sex and age group (20–64, 65–79, and ≥80 in the main analyses). In preliminary analyses, the age groups 20 to 39 and 40 to 64 were examined separately, but were combined because of similar results and to reduce random variation. These analyses are presented as secondary results. Models were estimated for full follow-up and for a 5-year follow-up, available across all surveys.

ROC-curves and areas under the curve (AUC) were used to assess the discriminative performance of AUDIT-C for alcohol-attributable events during the 5-year follow-up, using the R package *riskRegression* [26]. Optimal cut-offs were identified using three criteria: the Youden index, the minimum distance to the upper-left corner of the ROC plane and the maximum product of sensitivity and specificity. As no single gold standard exists for cut-off selection, optimal values were determined by considering concordance across these widely used criteria [27,28].

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Analyses were conducted using R version 4.5.0 [29]. The study was not pre-registered and should, therefore, be considered exploratory.

RESULTS

Table 1 presents basic information on the study population. AUDIT-C data were available for 95 477 participants (40 550 men and 54 927 women). During 879 964 person-years of follow-up (mean = 9.2 years), 1444 incident alcohol-attributable events occurred, including 846 within 5 years from baseline. Distributions of AUDIT-C scores by age and sex are shown in Table S1.

Risk of alcohol-attributable events by AUDIT-C score

Figure 1 presents HRs for register-based alcohol-attributable events across AUDIT-C scores compared with score 1, using the maximum follow-up time. The vertical axis is displayed on both logarithmic and linear scales. Results were visually identical when the follow-up was restricted to 5 years. The hazard increased approximately exponentially with increasing AUDIT-C score, corresponding to a near-linear increase on the logarithmic scale (Figure 1, left panel). When modelled as a continuous variable and adjusted for age group and sex, each one-point increase in AUDIT-C score was associated with a 49% higher hazard of alcohol-attributable events (HR = 1.49, 95% CI = 1.45–1.53).

TABLE 1 Number of individuals[a], incident alcohol-attributable events, person-years of follow-up and incidence rates[b] in the data overall and by sex and age group.

		Men			Women		
	Total	<65 years	65–79 years	≥80 years	<65 years	65–79 years	≥80 years
n	95 477	25 150	11 672	3728	33 523	14 877	6527
Full follow-up							
Events	1444	666	289	46	321	105	17
Person-years	879 964	243 818	100 115	23 211	331 044	136 553	45 223
Incidence rate	185	283	317	183	103	86	42
5-year follow-up							
Events	846	370	185	32	187	59	13
Person-years	462 303	124 170	55 157	15 415	166 744	72 369	28 448
Incidence rate	209	316	360	193	121	91	47

[a]Restricted to those without an event before baseline and with Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) score available.
[b]Incidence rates are weighted and presented per 100 000 population per year.

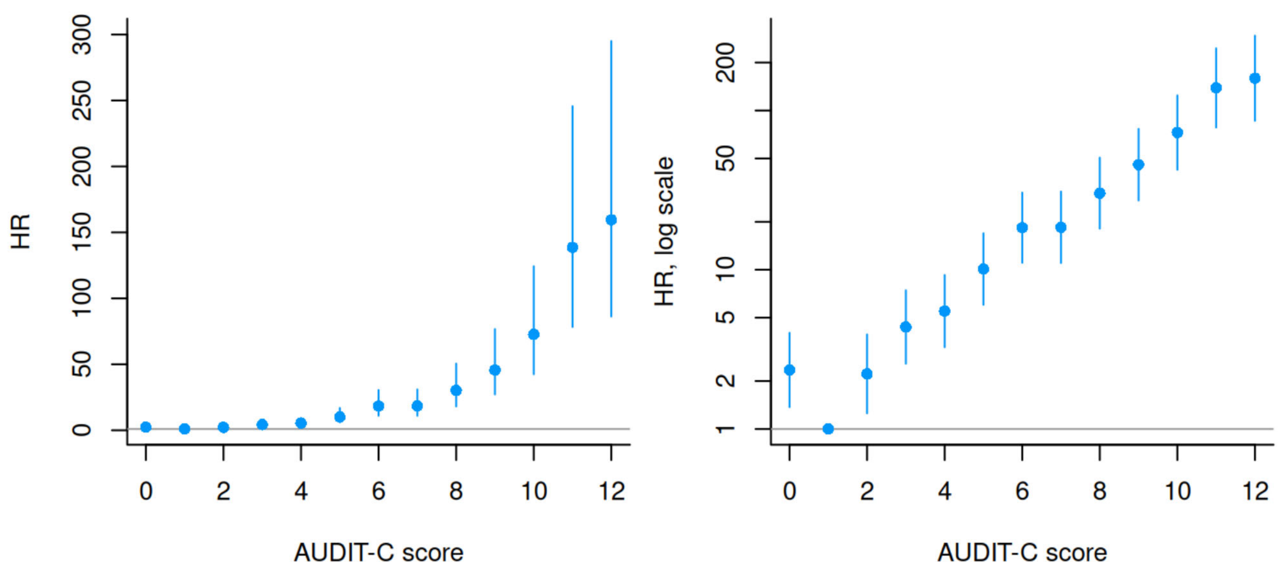

FIGURE 1 Unadjusted hazard ratios (HR) for register-based alcohol-attributable outcomes by Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) score, with a maximum follow-up time. HRs are shown on a linear scale (left) and logarithmic scale (right) on the vertical axis (HR = 1 for AUDIT-C score of 1).

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The right-hand panel of Figure 1 shows that abstainers (score 0) had a significantly higher risk than participants scoring one point, who were, therefore, used as the reference group. In the 2011 and 2017 surveys, where previous drinking was measured dichotomously, approximately one-third and approximately two-fifths of abstainers, respectively, were former drinkers (2011: 6%/18.4%; 2017: 9.1%/22.0%).

The increase in risk per AUDIT-C point was significantly greater among women than men (Figure 2; Table S2) (P < 0.001 for the sex × AUDIT-C interaction). On average, each additional point was associated with a 61% increase in hazard among women (HR = 1.61, 95% CI = 1.55–1.67) and a 45% increase among men (HR = 1.45, 95% CI = 1.40–1.49). Risk was already significantly elevated at an AUDIT-C score of 2 for women and 3 for men. Although risks at scores 2 to 4 were substantially higher than at score 1, they remained considerably lower than among participants with the highest AUDIT-C scores.

The slope of the association was similar across age groups (right hand side of Figure 2) (P = 0.12 for age group × AUDIT-C interaction; this was not modified by sex: P = 0.55 for the three-way interaction with sex). However, because of main effects of age, the risk was almost twice as high in the two older groups compared with those 20 to 64 years old with the same sex and AUDIT-C score (Table S2) (65–79 years versus <65 years: HR = 1.86, 1.63–2.11; ≥80: HR = 1.86, 1.42–2.45).

Figure 3 shows the fitted 5-year probabilities of alcohol-attributable events by age, sex and AUDIT-C score, illustrating the absolute risk levels and complementing the relative differences shown in Figures 1 and 2. For example, at an AUDIT-C score of 5, the

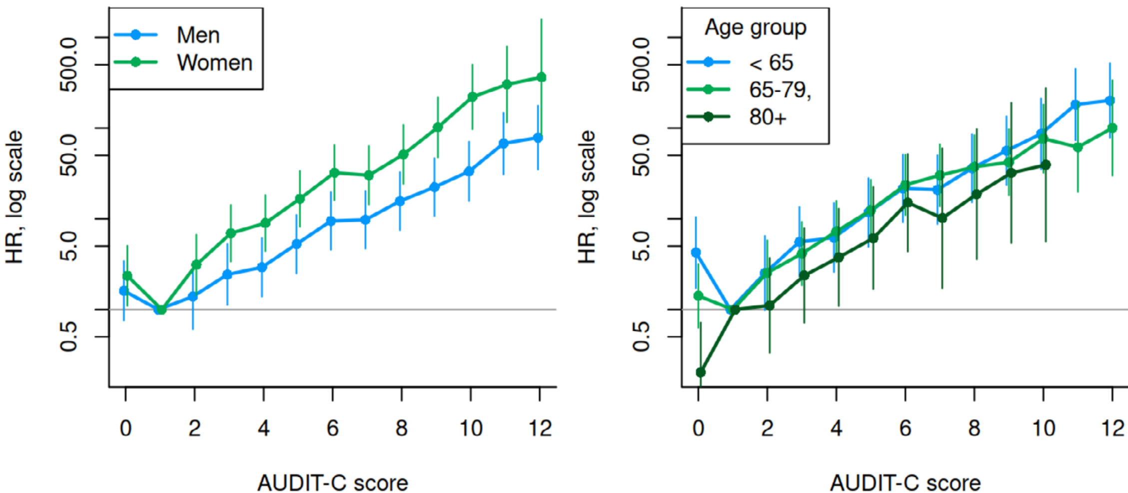

FIGURE 2 Hazard ratios (HRs, using logarithmic scale, HR = 1 for AUDIT-C score of 1) for register-based alcohol-attributable outcomes by Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) score and by sex (with age adjusted for) on the left and by age group (with sex adjusted for) on the right, with maximum follow-up time.

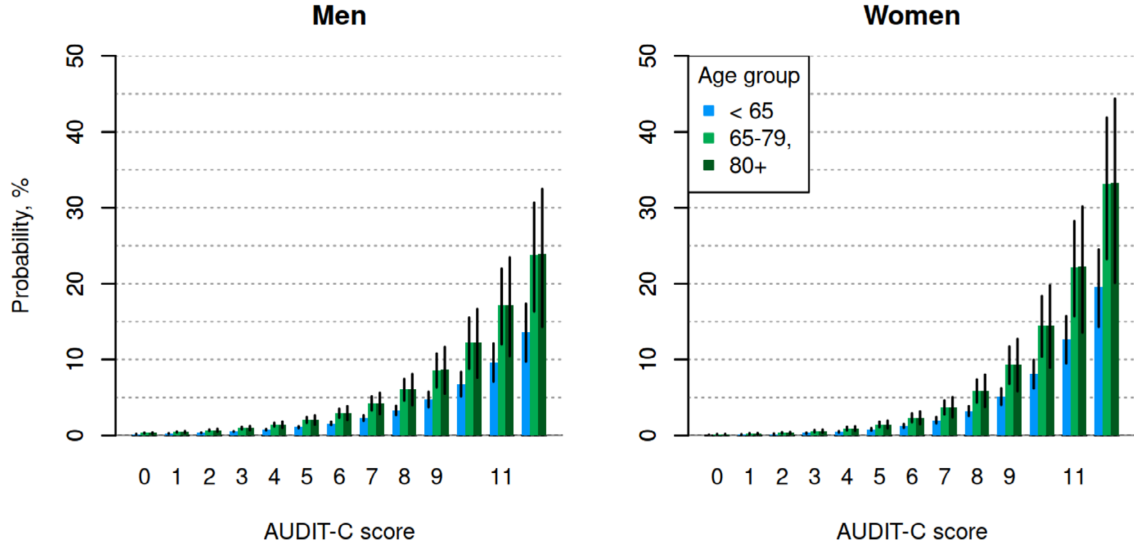

FIGURE 3 Five-year probabilities with 95% CIs of the event from the model shown in Table S2 fitted with the full follow-up data.

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estimated 5-year probability of an alcohol-attributable event ranged from 0.8% among women 20 to 64 years old to 2.0% among men ≥80 years old.

The balance between sensitivity and specificity: ROC curves and optimal cut-off values

AUDIT-C demonstrated acceptable discrimination for predicting alcohol-attributable events during the 5-year follow-up available for all surveys (Figure 4). AUC ranged from 74.8 to 83.2 across sex and age groups.

Age- and sex-specific sensitivities and specificities for alternative AUDIT-C cut-offs are presented in Table 2, with cut-offs identified as optimal by three criteria highlighted in red. Based on at least two of the three criteria, the suggested cut-offs were 6 points for men 20 to 64 years old, 5 for men 65 to 79 years old and 3 for men ≥80 years old; and 5 points for women 20 to 64 years old, 3 for women 65–79 years old and 2 for women ≥80 years old. In the 20 to 39 age group, greater heterogeneity was seen across the different optimization criteria; however, two of the three criteria suggested the same cut-off values as those identified for individuals 40 to 64 years (Table S3).

When compared with the current cut-off recommendations, applying these cut-offs would keep the prevalence of AUDIT-C positives unchanged among men and women 20 to 64 years old (35% and 19%, respectively, in our data). The prevalence would decrease among men 65 to 79 years old from 42% to 30%, increase among men ≥80 years old from 14% to 28%, increase among women 65–79 years old from 16% to 26% and increase among women ≥80 years old from 3% to 15%.

DISCUSSION

This large population-based study demonstrates that AUDIT-C is a valid instrument for identifying individuals at risk of alcohol-attributable harm requiring medical attention across age groups and in both men and women. The hazard of subsequent alcohol-attributable events increased approximately exponentially with increasing AUDIT-C scores. Risk was already elevated at an AUDIT-C score of 2 compared with score of 1 among women and the overall sample, and at a score of 3 among men. The increase for each AUDIT-C point was greater among women than men, but did not differ by age.

With respect to discrimination of individuals at risk of future alcohol-attributable harm within 5 years, our results indicate that lower AUDIT-C cut-offs are required for women and older adults than for men and people 20 to 64 years old. The suggested optimal cut-offs were 2 points for women ≥80 years old, 3 points for women 65 to 79 years old and men ≥80 years old, 5 points for women 20 to 64 years old and men 65 to 79 years old and 6 points for men 20 to 64 years old. These findings underscore the heterogeneity of the population ≥65 years with respect to vulnerability to alcohol-attributable harm. Nevertheless, as discussed below, these cut-offs should be interpreted as suggestive rather than prescriptive.

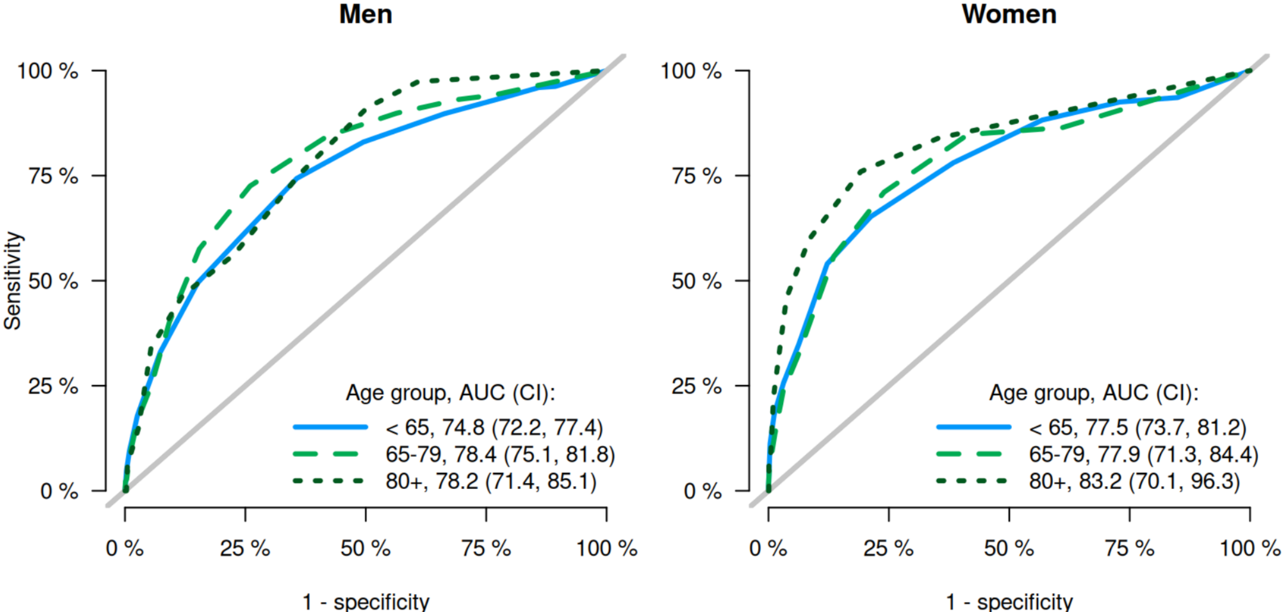

FIGURE 4 Receiver operating characteristic (ROC) curves illustrating the relationship between sensitivity and specificity in different points of the Alcohol Use Disorder Identification Test – Consumption (AUDIT-C) score, by sex and age group. Area under the curve (AUC) of 100% means perfect classification of observations and AUC of 50% (the line would equal the grey diagonal line on the graph) means classification is no better than random classification.

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TABLE 2 Sensitivity, specificity and the values of the optimality criteria for different values of the AUDIT-C score.

Sex	Age group	Cut-off	Sensitivity	Specificity	Youden	Distance to (0,1)	Product
Men	<65	≥1	0.962	0.107	0.069	0.894	0.103
		≥2	0.960	0.141	0.101	0.860	0.135
		≥3	0.938	0.207	0.145	0.795	0.194
		≥4	0.897	0.337	0.234	0.671	0.302
		≥5	0.830	0.505	0.335	0.523	0.419
		≥6	0.744	0.643	0.387	0.439	0.478
		≥7	0.603	0.760	0.363	0.464	0.458
		≥8	0.495	0.849	0.344	0.527	0.420
	65–79	≥1	0.942	0.235	0.177	0.767	0.222
		≥2	0.931	0.309	0.240	0.694	0.288
		≥3	0.899	0.436	0.334	0.573	0.392
		≥4	0.844	0.579	0.424	0.449	0.489
		≥5	0.725	0.740	0.465	0.378	0.537
		≥6	0.575	0.846	0.421	0.452	0.487
		≥7	0.402	0.908	0.309	0.606	0.364
		≥8	0.250	0.946	0.196	0.752	0.236
	≥80	≥1	0.974	0.391	0.365	0.609	0.381
		≥2	0.912	0.496	0.409	0.511	0.453
		≥3	0.754	0.637	0.391	0.439	0.480
		≥4	0.563	0.773	0.336	0.493	0.435
		≥5	0.464	0.881	0.345	0.549	0.409
		≥6	0.339	0.946	0.285	0.664	0.320
		≥7	0.148	0.972	0.120	0.853	0.143
		≥8	0.091	0.987	0.078	0.909	0.090
Women	<65	≥1	0.936	0.151	0.087	0.852	0.141
		≥2	0.925	0.271	0.196	0.733	0.250
		≥3	0.882	0.431	0.314	0.581	0.381
		≥4	0.781	0.616	0.397	0.442	0.481
		≥5	0.652	0.788	0.440	0.407	0.514
		≥6	0.540	0.878	0.418	0.476	0.474
		≥7	0.348	0.937	0.285	0.655	0.326
		≥8	0.257	0.969	0.225	0.744	0.249
	65–79	≥1	0.864	0.390	0.254	0.625	0.337
		≥2	0.848	0.586	0.434	0.441	0.497
		≥3	0.711	0.760	0.471	0.376	0.540
		≥4	0.558	0.864	0.422	0.463	0.482
		≥5	0.321	0.939	0.260	0.681	0.302
		≥6	0.237	0.970	0.206	0.764	0.229
		≥7	0.135	0.987	0.122	0.865	0.133
		≥8	0.084	0.994	0.078	0.916	0.084
	≥80	≥1	0.839	0.647	0.486	0.388	0.543
		≥2	0.760	0.808	0.568	0.307	0.614
		≥3	0.598	0.916	0.514	0.411	0.548
		≥4	0.458	0.963	0.421	0.543	0.441
		≥5	0.225	0.989	0.214	0.775	0.222

(Continues)

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TABLE 2 (Continued)

Sex	Age group	Cut-off	Sensitivity	Specificity	Youden	Distance to (0,1)	Product
		≥6	0.081	0.996	0.077	0.919	0.081
		≥7	0.081	0.998	0.079	0.919	0.081
		≥8	0.081	0.999	0.080	0.919	0.081

Notes: The cut-off point defines the smallest score in the high-risk group. Red indicates the optimal cut-off value for each optimality criterion.
Abbreviation: AUDIT-C, Alcohol Use Disorder Identification Test – Consumption.

Implications of results on risks by AUDIT-C score

Alcohol-attributable register entries primarily capture relatively severe outcomes and do not capture minor harms. Nevertheless, risk was elevated from a score of 2 onward. Scores of 2 to 4 reflect drinking a few drinks monthly or weekly, with rare or non-existent heavy episodic drinking occasions. Several factors may explain this: severe alcohol-attributable outcomes can occasionally occur at lower levels of consumption; some registered events are not highly severe (e.g. F10.0 acute intoxication); alcohol-consumption is commonly under-reported [30]; and AUDIT-C was measured at a single time point, while drinking patterns may change.

The implications of the shape of the risk curve warrant careful consideration. The finding that risk increases from very low AUDIT-C scores is consistent with the message that no safe level of alcohol consumption can be established [31] and indicates that alcohol harm can be reduced at all levels of consumption by alcohol policy [32]. However, the results do not imply that absolute risk at low levels is high. The convex, approximately exponential risk function indicates that risk increases only modestly at lower levels of consumption. Judgements about acceptable risk ultimately depend on individual preferences and societal values—empirically, ROC-based analysis can identify the scores that best discriminate between individuals who will and will not experience the outcome. At the other end of the continuum, the steep increase in risk at higher AUDIT-C values highlights the importance of further assessment to guide appropriate responses, such as brief interventions for at-risk alcohol use and more intensive medical and psychosocial treatment for alcohol use disorder [33].

Implications of the results on cut-off values

In the research literature, recommended AUDIT-C cut-offs vary by population, reference outcome and the preferred balance between sensitivity and specificity. In the United States, Bush *et al*. [1] prioritized sensitivity and proposed a cut-off of 3 points, or 4 for higher specificity, using past-year heavy drinking and Diagnostic and Statistical Manual of Mental Disorders (DSM)-III alcohol abuse/dependence as reference standards, while Bradley *et al*. [34] recommended 2 points for women based on DSM-IV criteria for past-year alcohol abuse and lifetime dependence. In Germany, aiming to improve specificity and using at-risk drinking and DSM-IV dependence and misuse, Rumpf *et al*. [9] suggested 5 points, emphasizing that cut-off selection depends on purpose and acceptable error rates. In Finland, cut-offs of 6 for men and 4 for women 25 to 64 years old have been recommended for hazardous drinking [6], while among those 65 to 74 years a lower definition of hazardous drinking resulted in a cut-off of 4 [7]. Compared with these Finnish recommendations for clinical screening, our findings support the same cut-off for men and a one point higher cut-off for women 20 to 64 years old, and greater variation among older adults (men: 5 and 3 for ages 65–79 and ≥80; women: 3 and 2, respectively) rather than a single cut-off of 4 for all ≥65 years.

Clear differences were observed in the optimal AUDIT-C cut-offs by age and sex. The need for lower cut-offs for women compared to men is well established [3] and were confirmed in this study, despite women having lower absolute 5-year risks at low AUDIT-C scores and exceeding men's risks only at higher AUDIT-C levels. With respect to age, the limited number of events in the oldest age group necessitates caution and further study. Nonetheless, the results clearly indicate that individuals ≥65 years and older should not be treated as a homogeneous group. Among men, the suggested cut-off was two points lower for those ≥80 years than those 65 to 79 years, while among women the corresponding difference was one point.

The mechanisms underlying these differences were not examined and warrant further investigation. Sex- and age-related variation in optimal cut-offs may reflect differences in frailty and vulnerability to alcohol-related harm, but alternative explanations are also plausible. Drinking patterns not specifically captured by the composite AUDIT-C score may influence risk and could be explored in future studies by examining the three items separately. Moreover, the alcohol-attributable outcomes examined here predominantly arise from long-term heavy drinking and, at any given AUDIT-C score, were more common among older adults. This suggests that AUDIT-C scores in older age may partly act as markers of cumulative lifetime exposure rather than current consumption alone. Conversely, younger individuals with high AUDIT-C scores may not yet manifest the chronic outcomes captured in this study, although they may face elevated risks of other harms, including injuries, violence and mental health problems such as depression [35,36]. Consistent with life-course evidence, avoiding sustained high alcohol intake across adulthood is critical for preventing later alcohol-related harm [37]. Finally, associations between AUDIT-C and harm may vary by outcome type and by age, which could not be assessed using the pooled measure used here. For example, AUDIT-C has been shown to correlate more strongly with alcohol use disorder severity among younger than among older working-age adults [8].

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When determining AUDIT-C cut-offs for specific applications, the purpose and its implications for the optimal trade-off between sensitivity and specificity should be considered. For face-to-face screening, prioritizing sensitivity and lower cut-offs is justified to reduce false negatives. For other uses, such as monitoring regional trends in alcohol-attributable risk, prioritizing specificity may be preferable to avoid false positives inflating prevalence estimates. In some cases, AUDIT-C may be best used as a continuous exposure, for example, in epidemiological analyses, while in other cases multiple categories that better capture different risk levels may be preferable to a simple dichotomous measure [21].

Our findings highlight the need for further research on AUDIT(-C) and actual alcohol-related harm across age groups and types of harm. Disaggregating the three AUDIT-C items may help clarify which aspects of drinking predict different outcomes in younger versus older adults, as evidence from Australia suggests that frequency of consumption may be a poor predictor of dependence in older drinkers [38].

Strengths and limitations

A major strength of this study is the use of a large, nationally representative dataset with AUDIT-C assessed via questionnaire and alcohol-attributable harm captured through registers, thereby reducing biases associated with self-report. Limitations include the low number of events among participants ≥80 years and the single time-point measurement of AUDIT-C, which does not capture temporal changes in drinking [20]. However, the use of incident events and consistent results across 5 years and full follow-up periods mitigate this concern. Registry-based outcomes primarily reflect more severe harms, and additional outcomes of varying severity would provide complementary evidence. Other individual-level factors influencing the risk of alcohol-attributable harm could not be accounted for. For example, information on participants' comorbidities and medications might have resulted in lower cut-offs for some individuals in the oldest age groups in particular and higher cut-offs for others. Finally, findings may not fully generalize to other countries. Notably, Finland's standard drink contains 12 g of alcohol, so AUDIT-C scores in our data were slightly lower than they would have been if using a 10-g standard drink.

CONCLUSION

AUDIT-C predicted register-based alcohol-attributable events effectively, with the risk per point higher in women than men, but similar across working-aged and older adults. Optimal cut-offs may differ by age and sex, with lower thresholds for older adults and women. The population ≥65 years is heterogeneous, highlighting the need to consider whether uniform AUDIT-C cut-offs or lower-risk drinking guidelines are appropriate for all adults in this age group. The selection of a cut-off and the balance between sensitivity and specificity should reflect the intended purpose of using AUDIT-C.

AUTHOR CONTRIBUTIONS

Pia Mäkelä: Conceptualization; funding acquisition; writing—original draft; methodology; writing—review and editing; supervision; project administration. **Jaakko Reinikainen:** Methodology; visualization; writing—review and editing; formal analysis. **Sarah Callinan:** Writing—review and editing. **Marke Jääskeläinen:** Conceptualization; writing—review and editing. **Kaisa Kuurne:** Writing—review and editing. **Tomi Lintonen:** Conceptualization; writing—review and editing. **Solja Niemelä:** Conceptualization; writing—review and editing. **Jonna Levola:** Conceptualization; writing—review and editing.

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DECLARATION OF INTERESTS

S.N. reports personal fees from dne Pharma, Otsuka, Lundbeck, Recordati and Takeda, all outside of this study.

DATA AVAILABILITY STATEMENT

Permission to use the data can be applied for from https://findata.fi/en/.

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APPENDIX 1: Definition of the outcome measure

Alcohol-attributable harm was operationalized by:

1. directly alcohol-attributable ICD-10 codes in the principle or secondary diagnoses in the Care register for Health Care: F10, E24.4, G31.2, G40.51, G62.1, G72.1, I42.6, K29.2, K70, K85.2, K86.00, K86.01, K86.08, Q86.0, Y91, T51, X45, O35.4, P04.3, E51.2 and E52;
2. directly alcohol-attributable ICD-10 codes in the underlying or contributory causes in the Cause of death register: F10, E24.4, G31.2, G40.51, G62.1, G72.1, I42.6, K29.2, K70, K85.2, K86.00, K86.01, K86.08, Q86.0, Y91, T51 and X45; and
3. by entries in the Prescription Register for purchases of prescription medicines used in the treatment of alcohol dependence (ATC codes N07BB01/disulfiram, N07BB04/naltrexone and N07BB05/acamprosate).

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