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TRANSITION PROBABILITIES FOR FOUR STATES OF ALCOHOL USE IN ADOLESCENCE AND YOUNG ADULTHOOD: WHAT FACTORS MATTER WHEN?

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Running head Transition probabilities of 4 drinking states

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ABSTRACT

Background and aims

Risky single occasion drinking (RSOD) is a health threat, particularly in younger ages. The study aimed to quantify transition probabilities (TPs) between abstinence, use of alcohol, RSOD and frequent RSOD, and to understand how TPs are associated with key demographic factors.

Design

Cohort study (baseline, two follow-ups). A Markov-model was fitted to estimate annual TPs and hazard ratios (HRs) for age, sex, and socioeconomic status (SES).

Setting

Adolescent and young adult general population of Munich (Germany) and surrounding areas.

Participants

3,021 persons aged 14-25 at baseline in 1995 followed-up in 1998/1999 (N=2,548) and 2003 to 2005 (N=2,210).

Measurements

Alcohol use, RSOD status, age, sex, and SES (subjective financial situation) were assessed in a standardized interview.

Findings

The highest TPs (>65%) were found for staying in the same drinking state. Higher age (HR for one year increase 0.87, 95% confidence interval (CI) 0.84-0.91), being female (hazard ratio (HR) 0.30, 95% CI 0.21-0.42), and a high SES (HR 0.64, 95% CI 0.43-0.97) were associated with a lower hazard to progress from use to RSOD. While age was predominantly associated with transitions between abstinence and alcohol use, sex was more relevant for transitions associated with RSOD and frequent RSOD.

Conclusions

German adolescents and young adults tend to be stable in the drinking states of abstinence, use of alcohol, risky single occasion drinking (RSOD), and frequent RSOD. Females are less likely to transition to riskier states and more likely to transition back from frequent RSOD, higher age is associated with lower hazard of transitioning, and participants of higher socioeconomic status are less likely to transition from ‘use of alcohol’ to ‘RSOD’.

Key words transition probability, alcohol, alcohol use disorders, adolescence, age, sex, socioeconomic status

INTRODUCTION

Risky single occasion drinking (RSOD) in adolescents and young adults has been shown to be associated with other risk behaviour (e.g. unprotected sex) as well as negative social (e.g. fights and aggression; neglecting school work) and health consequences (e.g. injuries; cognitive impairments) [2-5]. Recent considerations of reframing definitions of alcohol use disorders (AUDs) emphasize the importance of heavy drinking as it underlies the phenomena that currently define AUDs [6, 7]. Consequently the present paper focusses on RSOD and its frequency.

RSOD is usually preceded by a history of drinking initiation and periods of low-risk use [8]. Recent research, e.g. the Addiction and Lifestyles in Contemporary Europe Reframing Addictions Project (ALICE RAP), investigated factors that influence the probability of transitioning between different states of substance use based on literature review methods [9, 10]. However, the literature review approach is limited because: (a) the relative importance of different factors for different transitions is based on subjective judgment; (b) the evidence is unsuitable for deriving quantitative estimates of transitions between states that could be used in epidemiological studies of harm.

The present study contributes to our understanding of transitions between drinking states (i.e. abstinence, use, RSOD and frequent RSOD (F-RSOD)), and the associations of key demographic factors (i.e. age, sex, and socioeconomic status (SES)) on different transitions, using a statistical modelling approach based on longitudinal data for a cohort of German adolescents and young adults aged 14-25 at baseline (1995).

Age is associated with developmental tasks as well as social and physiological maturing processes relevant to alcohol use behaviour [11, 12]. Adolescence and young adulthood are critical ages with respect to alcohol use: especially in the European and other high income regions most people initiate drinking in (early) adolescence, with risky patterns often emerging during adolescence [13, 14], and AUDs being prevalent in early adulthood [15, 16]. For our cohort, we hypothesized that the magnitude of transition probabilities (TPs) between states would reduce with age.

Man and women tend to differ in their drinking behaviour, with proportions of abstainers being higher in females and risky patterns of use being more prevalent among males– although absolute effect sizes depend on country and particular operationalization of RSOD [13, 17, 18]. While there are biological differences in the harm associated with alcohol use [19], it has been argued that the drinking behaviour itself is largely culturally determined [20]. Different social roles, drinking norms, and expectations associated with being male or female still strongly influence drinking behaviour [21, 22]. For our cohort, males were hypothesized be more likely to initiate alcohol use and to transition more rapidly to risky patterns of use.

An extensive body of literature shows that SES is another key factor related to alcohol use patterns with some variation by country and sex [23-25]. In high income countries in general [26] and Germany specifically [23] people of lower SES tend to be more polarized than the general population in their drinking – with increased prevalence of both abstention and RSOD. Understanding the SES impact on TPs between drinking states might contribute to our understanding of the substantial socioeconomic differences in alcohol-attributable mortality [27]. For our cohort, persons of lower SES were hypothesized to be more likely to transition from use to abstinence as well as to RSOD/ F-RSOD.

Objectives of the present paper were:

1. to calculate TPs between different drinking states (abstinence, use, RSOD and F-RSOD) on a sample of German adolescents and young adults aged 14-25 at baseline;
2. to investigate the association of the demographic factors age, sex, and SES with each transition;
3. to simulate age- and sex-specific prevalence over the early life course (14-30 years) based on the calculated TPs.

METHODS

Panel data from three waves assessing a sample of German adolescents and young adults were used to estimate TPs between a number of mutually exclusive drinking states in a Markov model [28]. TPs represent the probability of being in a certain drinking state at the end of a year, conditional on the drinking state at the start of the year. Hazard ratios (HRs) were calculated for the covariates age, sex, and SES. The HR is the proportionate change in the instantaneous probability of moving from drinking state *i* to drinking state *j* due to a covariate. Age- and sex-specific TPs were used to simulate the prevalence of different drinking states over the early life. Further details on the methods are provided below.

Sample description

We used data from the prospective-longitudinal Early Developmental Stages of Psychopathology Study (EDSP). The EDSP aimed to investigate the course of substance use disorders in youth and young adulthood. In 1994 a random sample was drawn from the population register of Munich, Germany, and surrounding areas. To archive a sufficiently large sample of abstainers that would initiate substance use in the following years, the sample was stratified by age groups 14-15, 16-21, and 22-24, sampled in a ratio 4:2:1. The sampling frame did not include any clusters. Sample weights inversely proportional to the sampling fraction accounted for the sampling frame as well as non-response rates at baseline to represent the baseline target-population (for details see [29]). The present study used data from the baseline assessment (T0 in 1995; N=3,021; response rate: 71%) and two follow-ups (FU1 in 1998/1999; N=2,548; response rate: 85% of baseline sample; FU2 in 2003 to 2005; N=2,210; response rate: 73% of baseline sample). The mean delay was 3.47 years (standard deviation 0.25) from T0 to FU1 and 5.19 years (standard deviation 1.34) from FU1 to FU2.

Individual respondents were excluded from the analysis if: (a) they had no follow-up observation (N=315); (b) they had missing values for alcohol use variables or covariates (N=26). Respondents with missing observations at FU1 were included based on the transition between T0 and FU2 (N=182). Drop-out bias was investigated using a multinomial logistic regression model predicting attrition at FU1/FU2 based on alcohol use, age, sex, and SES.

Assessment

EDSP used the computer-assisted personal interview version of the Munich-Composite International Diagnostic Interview (M-CIDI) [30]. The interview section assessing information on quantity and frequency of alcohol use and AUDs was only accomplished when the participant reported at least 13 drinking occasions in the past year. The subjective financial situation as measure of SES was assessed with the question “How would you overall judge your financial situation?” (“very good” to “very bad” on a five point Likert scale).

States of alcohol use and covariates

Previous research has indicated a lack of validity of standardized instruments assessing AUDs, particularly in younger samples [31-33]: high prevalence of abuse diagnosis has been shown to be driven by the hazardous use criterion (e.g. driving under the influence) and diagnosis of alcohol dependence has been shown to be driven by rapid initial tolerance and confusion between withdrawal and a hangover. Conceptualizing AUDs using consumption patterns might be more useful (in terms of prevention), adequate (as it depends less on cultural norms), and less stigmatizing (as it situates persons on a continuum) [6, 7]. We therefore based our operationalization on frequency of RSOD. A risky single occasion was defined as drinking at least five standard drinks (containing nine grams of ethanol) per occasion [5]. A pattern of RSOD was defined at least one RSO per month and not more than two RSOs per week. As frequency of RSOD has been associated with higher risks [4], a pattern three or more RSOs per week was defined as frequent RSOD (F-RSOD). Abstinence was defined as less than 13 drinking occasions in the past year. Frequencies and percentages of the four drinking states at each of the three waves are shown in Table 1.

- Insert Table 1 here -

A total of 4,736 observed transitions were available for analysis (including the null transitions, where the drinking state was unchanged). Table 2 shows transition counts by time interval and drinking state.

- Insert Table 2 here -

As covariates we used sex, age, and SES. Sexes were balanced (baseline: 49.3% females, 50.7% males; FU2: 48.6% females, 51.1% males). Age was operationalized as a continuous variable and varied between 14 and 25 years at T0 and between 21 to 34 years at FU2.

Education and income are common proxy measures of SES. However, these proxies have serious limitations for use in adolescents and young adults. Education may be still ongoing, and individual income may be low yet the person be of high SES. Therefore SES was operationalized as self-reported personal financial situation [29]. Self-reported and subjective measures have recently been shown to be useful and robust measures of SES [34] and predictors of health and health-related behaviour [35]. Subjective financial situation was dichotomized into low ("very bad", "bad", and "neither good nor bad") and high SES ("good" and "very good"). 34.5% and 35.2% were classified as high SES and at T0 and FU1, respectively.

Modelling

The aim of the modelling was to construct trajectories of drinking patterns in the population that would be suitable for use in quantitative epidemiological work (e.g. for policy appraisal or burden-of-harm studies). Therefore, the study aimed to produce a model with annual TPs between drinking states [36]. To develop the model, we first estimated a continuous-time, time-homogeneous Markov process, from which we were then able to derive annual TPs. Mathematically TPs referring to a time interval of t are calculated via the matrix exponential of the intensity matrix, Q [37].

We estimated the instantaneous risk of transitioning (q_{rs}) from state r to state s using Broyden-Fletcher-Goldfarb-Shanno (BFGS) quasi-Newton methods that aim to maximize log-likelihood [38].

95% confidence intervals (CIs) were calculated by repeatedly sampling (N=1000) from the distribution of the maximum likelihood estimates of the log(q_{rs}). Since it is challenging to estimate the instantaneous risks of transitioning between the states simultaneously [37], we necessarily restricted the set of instantaneous transitions that were permissible in the Q-matrix of all possible transitions. Starting with the full model we gradually restricted allowed transitions beginning with the most remote transitions (i.e. between abstinence and F-RSOD) until convergence was reached. Model goodness-of-fit was assessed using a Pearson-type contingency table test statistic [39], comparing observed rates of transitions between states to the ones predicted by the candidate Markov model. One-year TPs were estimated based on the instantaneous risks of transitioning, using each participant's exact duration of delay between assessments. Note that an instantaneous risk of transitioning of 0 does not prevent the estimation of TPs between those states since the model assumes that people can transition by passing through other states within any given year. To model the impact of covariates (age, sex and SES), we considered covariate-adjusted TPs, using a HR approach. All TP estimation procedures were undertaken using version 1.3 of the msm package [40] for R [v.3.1.0; 41]. The impact of sample weights was analysed in a sensitivity analysis replicating the observations in accordance with sample weights (expanded by 100). Further details are reported in the Supporting information.

Simulations

To graphically summarise our findings, and demonstrate their applicability to epidemiological modelling, we used the derived TPs to simulate drinking state prevalence over the adolescence and early adult life course (aged 14 to 30) of a cohort with baseline prevalence drawn from the Munich data. Uncertainty in the trajectories is described by sampling from the estimation error – specifically we sample 1000 TP matrices for each gender using the CIs generated when the TP matrix is estimated. Prevalence is then simulated, with individual TPs sampled from a truncated normal distribution [42], defined using the mean and upper and lower bounds of the relevant age- and sex-specific TP matrix.

RESULTS

Transition probabilities

After stepwise restriction of allowed transitions, the final model included all adjacent transitions plus the transition from abstinence to RSOD. The respective Q-matrix of the final four-state Markov model is shown in Box 1. The Pearson-type test for model goodness-of-fit is challenging to set up for more ambitious models which include covariates and long follow-up periods (due to sparse contingency tables). For our operationalization, we achieve a *T* statistic of 600.6 for a χ^2 test with between 116 and 144 degrees of freedom. This result indicates some issues with model fit, which we discuss later (for details see Supporting Information Table S3).

The annual TPs adjusted by age, sex, and SES and the respective 95% CIs are shown in Table 3. The highest probabilities were observed for staying in the current state ranging from 67.8% (95% CI 63.7-71.5%) for RSOD to 79.1% (95% CI 75.3-80.4%) for abstinence. The lowest TPs were observed between non-adjacent states (<5%). While the probability to transition to F-RSOD in the following year when being in the state of RSOD was 5.5% (95% CI 4.5-6.6%), the probability to reduce the frequency of RSOD when being in the state of F-RSOD was 19.4% (95% CI 15.0-24.3%). TPs taking sampling weights into account replicated the findings (see Supporting Information Table S1).

- Insert Table 3 here -

Covariates age, sex, and SES

For all allowed instantaneous transitions (see Box 1) HRs were calculated for the covariates age, sex, and SES (see Table 4). Females were less likely to progress from use to RSOD (HR 0.30, 95% CI 0.21-0.42) or from RSOD to F-RSOD (HR 0.63, 95% CI 0.41-0.98) and more likely to go reduce frequency of RSOD (HR 1.65, 95% CI 1.04-2.62). Higher age was associated with lower hazards of transitioning for the transitions abstinence to use (HR 0.91, 95% CI 088-0.93), use to RSOD (HR 0.87, 95% CI 0.84-0.91), and use to abstinence (HR 0.90, 95% CI 0.86-0.94). Participants of higher SES had lower hazards to transition from use to RSOD (HR 0.64, 95% CI 0.43-0.97).

The models based on replicating the observations in accordance with sample weights (expanded by 100), reproduced the findings with the only difference that the HR for transitioning from F-RSOD to RSOD was not significant anymore (HR 1.44, 95% CI 0.91-2.28) but females were more likely to transition from RSOD to use (HR 1.75, 95% CI 1.20-2.57; see Supporting Information Table S2).

- Insert Table 4 here -

Simulations

The simulations of prevalence over age are shown in Fig. 2. A clear sex-gap was visible in the simulated prevalence of all drinking states. While for abstinence and use (excluding RSOD and F-RSOD) females showed higher prevalence, the prevalence of RSOD and F-RSOD was clearly higher in men. The prevalence of all states stabilized around in the early twenties, with RSOD showing a peak around the age of 18. Simulations based on TPs from the expanded samples replicated that pattern and are shown as Supporting Information Fig. S1.

- Insert Fig. 2 here -

Attrition

The multinomial logistic regression showed lower odds of attrition at FU1 for participants of the lower SES (odds ratio 0.80, 95% CI 0.65-0.99). No other variable was a significant predictor for attrition at any of the FUs (see Supporting Information Table S3).

DISCUSSION

A four-state Markov model was fitted in order to calculate annual TPs and HRs for the covariates age, sex, and SES. The presented model is a significant contribution to the very small literature on Markov-models for alcohol use [43, 44].

Highest probabilities (≥65%) were found for staying in the same drinking state. Lowest TPs were found between non-adjacent states (<5%). The influence of covariates was overall as expected: females were less likely to transition to 'later' states and more likely to transition back from F-RSOD, higher age was associated with lower hazards of transitioning, particularly for transitions between use and abstinence, and participants of higher SES were less likely to transition to RSOD when being a user. While age was predominantly associated with transitions between use and abstinence, sex was more relevant for transitions associated with RSOD and F-RSOD. The simulations mirrored the overall picture of alcohol use described in the introduction with respect to prevalence over age as well as sex gaps.

Interpretation of results

The calculated annual TPs showed that the drinking states are relatively stable. Interestingly, while every fifth participant decreased frequency of RSOD within one year, RSOD was associated with a relatively low TP to F-RSOD (about 5%). This indicates that engaging in RSOD is not associated with a clearly elevated probability to increase the frequency within one year. Males were more likely to increase the frequency of RSOD (with higher hazards of transitioning form use to RSOD and from RSOD to F-RSOD). However, as F-RSOD is associated with other risk behaviour as driving under the influence and considerable social and health consequences [3-5], it would be important to identify further factors that put adolescents and young adults at risk to engage in F-RSOD. In a similar analysis of TPs, Jackson et al. [45] found that persons with a family history of alcohol dependence had a lower probability to transition out of 'large effect drinking'. Genetic studies have shown that initiation of alcohol use is more strongly influenced by environmental factors while genetic factors were important for explaining more risky patterns as RSOD ('binge drinking', 'getting drunk') [46].

In simulations we estimated the prevalence of all four drinking patterns, its change trends over age (14 to 30), and sex differences. Taking differences in operationalization into account, the simulated prevalence matched recent findings from a German, representative sample on use, RSOD, and AUDs fairly well [47]. The simulated prevalence showed that sex differences among users mainly go back to higher prevalence of RSOD and F-RSOD among men. It should be noted that the user rates do not mirror mean daily consumption but just the fact that someone used alcohol in the past year and was not categorized as RSOD or F-RSOD.

Methodological limitations

The present study was able to investigate TPs, and simultaneously test hypotheses on the influence of different covariates for specific transitions. As mentioned above, due to restricted sample size, applying a statistical model required focusing on a small set of covariates and restriction of allowed instantaneous transitions. The model allowed for all adjacent transitions and assumed the transition through another state for all other transitions except the transition from abstinence to RSOD. The restriction of allowed instantaneous transitions did not prevent the estimation of TPs, however, respective TPs might be underestimated. The Pearson-type test for goodness-of-fit suggested issues with model fit. Examination of the table of deviances for the test suggests that model mis-specification is dominated by the RSOD state. In early stages of the process, the model underestimates transitions from abstinence to RSOD, with subsequent underestimation of transitions from RSOD to use or abstinence at later stages. However no patterns (over time or time interval) are seen in the deviances for a given transition, which suggests the time homogeneity assumption, given consideration for age as a covariate, is reasonable.

It should be noted, that while alcohol use was reported for the past year the delay between assessments was greater than one year. Consequently there is an unobserved period for which the drinking state could not be established. While this might dilute the results (i.e., create unsystematic bias) it is unlikely to systematically bias the findings. It would have been more precise to have annual observations of drinking states. The Markov property assumes that the transition intensity is independent of the amount of time spent in the state. In the present case it might in fact be the case that TP decreases with the time spend in a drinking state. However, to our judgment the analysis presented was the most appropriate given the data available.

It should be noted that one of the key operationalizations of the present study was RSOD, which implicitly assumes a limited time interval where a minimum of five standard drinks is consumed. This time interval was not measured in the study.

Within Germany, the area around Munich is a particularly wealthy area [48], limiting the variance in SES. The latter might have limited our capacity to find more effects of SES, e.g. for transitions to abstinence or F-RSOD. Attrition was slightly higher in participants of high SES. However, this is unlikely to have biased the results considerably.

Generalizability of results is technically limited to Munich and surrounding areas around the turn of the Twenty-First century. Even though drinking cultures in Europe are converging over the past years, there is still variation with respect to choice of beverages, drinking patterns and per capita consumption [49]. However, the overall picture matches our knowledge on prevalence, age trends and, sex gaps for Europe and Germany in particular fairly well.

Future research

The present study shows how knowledge gained from literature reviews can be empirically tested using a modelling approach based on representative panel data. Future research should consider using the same approach on larger datasets including other relevant covariates such as comorbidity, age of onset, and genetic vulnerability [50-53]. In the present study the age span was limited to youth and young adulthood. Especially in elderly drinking patterns seem to change again as major life changes (e.g. retirement) happen [54]. In aging societies as most European societies [55] TPs and relevant covariates in this age group should receive more attention [56].

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Contributors CP is the guarantor and has had overall responsibility of all steps. JR and RP supervised the whole working process. All authors contributed to conception and decisions on statistical analysis of the data. DM performed most of the statistical analyses and the modelling work. CP wrote the first draft of the manuscript, and contributed to the statistical analysis. All authors contributed to the writing and revision of the manuscript and approved of the submitted version.

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SUPPORTING INFORMATION

Figure S1 Simulated prevalence of all four drinking states over age by sex, based on weight data with expansion factor 100. Dashed lines indicate 95% confidence interval.

Table S1 Annual transition probabilities in % between all four drinking states and respective 95% confidence intervals. Estimations are based on the weighted data with expansion factor 100, the standard error from the unexpanded calculations was applied to correct for overestimation of precision. Transition probabilities in each row sum to 1. Figures in bold face indicate allowed instantaneous transitions, figures in the diagonal reflect probability to stay in one use state.

Table S2 Hazard ratios and their 95% confidence interval from weighted data with expansion factor 100 for the covariates age, sex and socioeconomic status, for all allowed instantaneous transitions. The standard error from the unexpanded calculations was applied to correct for overestimation of precision. Bold face indicates the more severe drinking state in each transition.

Table S3 Multinomial logistic regression predicting attrition at first or second follow-up (FU1 and FU2) based on age, sex, and socioeconomic status (SES).

Table S3 Pearson-type goodness of fit test: deviance table. Normalised squared difference between the observed and expected transitions. Sing indicates the direction of difference in fit.

Table 1 Frequencies and percentages of drinking states at T0, first follow-up (FU1), and second follow-up (FU2).

	T0	FU1	FU2
Abstinence (%)	1,492 (49.4)	599 (23.7)	380 (17.2)
Use (%)	903 (29.9)	1,025 (40.6)	938 (42.4)
RSOD (%)	476 (15.8)	721 (28.5)	667 (30.2)
F-RSOD (%)	150 (5.0)	181 (7.2)	225 (10.2)
Total (% of T0)	3,021 (100)	2,526 (100)	2,210 (100)

RSOD risky single occasion drinking (at least once per month and not more than two times per week in the past year); F-RSOD frequent risky single occasion drinking (at least three times per week).

Table 2 Transition count matrix: number of single transitions between drinking states available for analysis. Transitions between baseline (T0) and second follow-up (FU2) were only included if information for first follow-up (FU1) were missing.

	Abstinence	Use	RSOD	F-RSOD	Total
T0-FU1					
Abstinence	463	430	319	33	1,245
Use	88	424	196	49	757
RSOD	44	134	176	40	394
F-RSOD	4	37	30	59	130
Total	599	1,025	721	181	2,526
FU1-FU2					
Abstinence	213	164	89	3	469
Use	100	474	215	44	833
RSOD	23	192	281	80	576
F-RSOD	3	38	28	81	150
Total	339	868	613	208	2,028
T0-FU2					
Abstinence	27	25	28	7	87
Use	9	34	14	4	61
RSOD	5	9	10	4	28
F-RSOD	0	2	2	2	6
Total	41	70	54	17	182
Total transitions available					
Abstinence	703	619	436	43	1,801
Use	197	932	425	97	1,651
RSOD	72	335	467	124	998
F-RSOD	7	77	60	142	286
Total	979	1,963	1,388	406	4,736

RSOD risky single occasion drinking (at least once per month and not more than two times per week in the past year); F-RSOD frequent risky single occasion drinking (at least three times per week).

Table 3 Annual transition probabilities in % between all four drinking states and respective 95% confidence intervals. Transition probabilities in each row sum to 1. Figures in bold face indicate allowed instantaneous transitions, figures in the diagonal reflect probability to stay in one use state.

	Abstinence	CI	Use	CI	RSOD	CI	F-RSOD	CI
Abstinence	**79.09**	75.27-80.74	**17.81**	16.03-20.14	**3.01**	2.44-7.38	0.09	0.06-0.27
Use	**6.38**	5.48-7.33	**73.88**	70.69-76.36	**18.99**	16.5-22.12	0.75	0.59-0.96
RSOD	1.13	0.91-1.41	**25.59**	21.92-29.63	**67.83**	63.74-71.52	**5.45**	4.52-6.57
F-RSOD	0.1	0.08-0.15	3.61	2.68-4.83	**19.42**	14.98-24.31	**76.87**	71.04-82.07

CI 95% confidence interval; RSOD risky single occasion drinking (at least once per month and not more than two times per week in the past year); F-RSOD frequent risky single occasion drinking (at least three times per week).

Table 4 Hazard ratios and their 95% confidence interval for the covariates age, sex, and socioeconomic status, for all allowed instantaneous transitions. Bold face indicates the more severe drinking state in each transition.

		Sex[1]		Age[2]		SES[3]	
Transition		HR	CI	HR	CI	HR	CI
Abstinence	→ **use**	0.85	0.70-1.02	0.91*	0.88-0.93	0.91	0.73-1.15
Abstinence	→ **RSOD**	0.37	0.11-1.32	1.18	0.89-1.56	16.27	0.28-938.41
Use	→ **RSOD**	0.30*	0.21-0.42	0.87*	0.84-0.91	0.64*	0.43-0.97
RSOD	→ **F-RSOD**	0.63*	0.41-0.98	1.00	0.95-1.05	0.94	0.67-1.30
Use	→ abstinence	1.16	0.87-1.55	0.90*	0.86-0.94	0.79	0.59-1.04
RSOD	→ use	1.21	0.83-1.78	1.01	0.96-1.06	0.74	0.47-1.15
F-RSOD	→ RSOD	1.65*	1.04-2.62	0.94	0.88-1.01	1.03	0.70-1.51

* Significant, α=5%; HR hazard ratio; CI 95% confidence interval; SES socioeconomic status; RSOD risky single occasion drinking (at least once per month and not more than two times per week in the past year); F-RSOD frequent risky single occasion drinking (at least three times per week).

1 Reference category was male sex

2 Reference category was younger age

3 Reference category was lower socioeconomic status

Box 1 Q-matrix of the Markov model showing allowed instantaneous transitions. RSOD risky single occasion drinking (at least once per month and not more than two times per week in the past year); F-RSOD frequent risky single occasion drinking (at least three times per week)

	Abstinence	Use	RSOD	F-RSOD
Abstinence	$-(q_{12}+q_{13})$	q_{12}	q_{13}	0
Use	q_{21}	$-(q_{21}+q_{23})$	q_{23}	0
RSOD	0	q_{32}	$-(q_{32}+q_{34})$	q_{34}
F-RSOD	0	0	q_{43}	$-q_{43}$

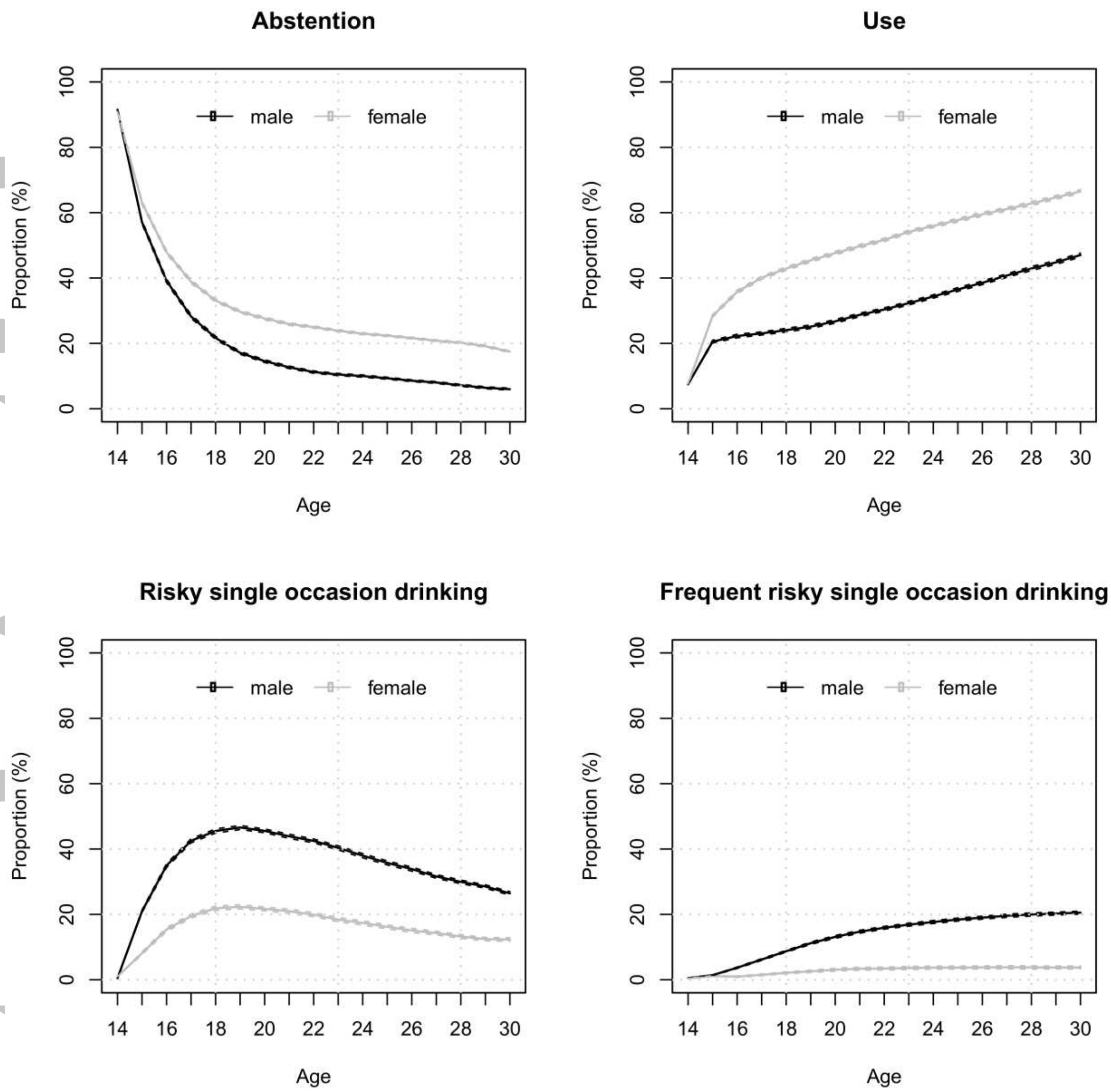

Figure 1 Simulated prevalence of abstinence, use, risky single occasion drinking, and frequent risky single occasion drinking by age and sex. Dashed lines indicate 95% confidence interval.