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# Identification of Latent Alcohol Use Groups and Transitions over Time Using a 9-Year Follow-Up Study in the Adult General Population

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## Keywords

Alcohol use disorder · Alcohol consumption · Longitudinal general population study · Latent groups and transitions · Latent Markov modelling

## Abstract

**Introduction:** Studies investigating latent alcohol use groups and transitions of these groups over time are scarce, while such knowledge could facilitate efficient use of screening and preventive interventions for groups with a high risk of problematic alcohol use. Therefore, the present study examines the characteristics, transitions, and long-term stability of adult alcohol use groups and explores some of the possible predictors of the transitions. **Methods:** Data were used from the baseline, 3-, 6-, and 9-year follow-up waves of the Netherlands Mental Health Survey and Incidence Study-2 (NEMESIS-2), a representative study of Dutch adults aged 18–64 at baseline ( $N = 6,646$ ; number of data points: 20,574). Alcohol consumption, alcohol use disorder (AUD), and mental disorders were assessed with the Composite International Diagnostic Interview 3.0. Latent Markov Modelling was used to identify latent groups based on high average alcohol consumption (HAAC) and AUD and to determine transition patterns of people between groups over time (stayers vs. movers). **Results:** The best fitting model resulted in four la-

tent groups: one nonproblematic group (91%): *no HAAC, no AUD*; and three problematic alcohol use groups (9%): *HAAC, no AUD* (5%); *no HAAC, often AUD* (3%); and *HAAC and AUD* (1%). *HAAC, no AUD* was associated with a high mean age (55 years) and low educational level (41%), and *no HAAC, often AUD* with high proportions of males (78%) and people with high educational level (46%). Eighty-seven percent of all respondents – mostly people with *no HAAC, no AUD* – stayed in their original group during the whole 9-year period. Among movers, people in a problematic alcohol use group (HAAC and/or AUD) mostly transitioned to another problematic alcohol use group and not to the nonproblematic alcohol use group (*no HAAC, no AUD*). Explorative analyses suggested that lack of physical activity possibly plays a role in transitions both from and to problematic alcohol use groups over time. **Conclusion:** The detection of three problematic alcohol use groups – with transitions mostly between the different problematic alcohol use groups and not to the group without alcohol problems – points to the need to explicitly address both alcohol consumption and alcohol-related problems (AUD criteria) in screening measures and interventions in order not to miss and to adequately treat all problematic alcohol users. Moreover, explorative findings suggest that prevention measures should also include physical activity.

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## Introduction

Per capita alcohol consumption in Europe (including the Netherlands) is the highest in the world [1] and the reduction of excessive or problematic alcohol use is a priority of Dutch health policy [2], as the harmful effects are evident. Problematic alcohol use is associated with a high burden of disease [3], societal costs [3, 4], several acute and chronic physical diseases [5], and increased mortality rates [6]. It occurs when there is (i) excessive drinking (i.e., high average alcohol consumption or frequent heavy drinking days [7]) or (ii) a maladaptive pattern of use leading to significant impairment and distress (alcohol use disorder: AUD). Research shows that both aspects of problematic alcohol use – excessive drinking and AUD – are related, but do not always co-occur [8–13]. Most research has focused on only one of the two aspects of problematic alcohol use or applied some theoretical definition of problematic alcohol use instead of using an empirical definition based on, for example, latent class analysis. This is unfortunate as a latent variable approach using both aspects of problematic alcohol use enables the detection of practically meaningful groups in the general population [14]. In turn, better knowledge about latent problematic alcohol use groups in the general population may prevent a relevant group from being overlooked in the screening and prevention of problematic use. Also, each problematic alcohol use group may be associated with their own characteristics and predictors of transitions to other groups over time. They may therefore need their own type of intervention to reduce specific types of problematic behaviour.

Until now, only a few studies have examined latent alcohol use groups considering both excessive drinking and alcohol-related problems. A longitudinal study among adolescents with high-risk of familial alcoholism [15] detected four latent groups, varying from abstainers to high-risk drinkers, based on increasing levels of drinking and AUD symptoms. No group with just one of the aspects was identified. Two cross-sectional studies, among adult workers and elderly, identified three latent groups: no problematic alcohol use; excessive drinking only; and co-occurrence of excessive drinking and alcohol-related problems [16, 17]. Notably, none of these studies identified a group with AUD but without excessive drinking, whereas previous population-based research using latent cluster analyses suggested the existence of such a group as they observed that not all alcohol-dependent people drink excessively [13]. Possibly, prior research using latent class analyses did not detect this group because they had rela-

tively small and selective samples. This problem could be resolved by applying the same technique to a general population sample with a large number of data points (large sample with multiple assessments).

Overall, the proportion of people with excessive drinking or AUD in the general population has remained stable over the past decades [18–20]. However, shifts between the groups may occur, and it is uncertain to which degree this occurs and in which direction. Among adolescents [15], transitions occurred most often in those with the most severe state (high level of both consumption and AUD symptoms) to the state with a moderate level of both aspects, but not to the state with low alcohol use levels or abstinence. Similarly, longitudinal population-based research on adults suggested that 3-year transitions from groups with DSM-5 AUD more often occur to excessive drinking only than to abstinence/low-risk-drinking [21]. It can be questioned to what extent improvement in AUD with continued excessive drinking is a desirable outcome as this is still associated with considerable health risks [3, 6, 7] and an increased risk of relapse into AUD [22]. A focus on transition to a group without any of the aspects of problematic alcohol use is therefore preferable. Moreover, given that the overall size of problematic alcohol use remains the same, it is also important to examine who develops excessive drinking and/or AUD among those without problematic alcohol use, i.e., not only the development of AUD [23, 24].

By using Latent Markov Modelling on data from four assessment waves (baseline, 3-, 6-, and 9-year follow-up) of the Netherlands Mental Health Survey and Incidence Study-2 (NEMESIS-2), a large, representative cohort of adults, the present study fills two gaps in our current knowledge. It will (i) identify latent groups of problematic alcohol use in the adult general population while taking into account both excessive drinking and AUD, and (ii) examine 3-year transitions of identified latent groups between all pairs of four consecutive waves and long-term stability (i.e., 9 years) of these groups. Moreover, to improve the detection of the latent groups, we will characterize these groups using a large range of covariates. Lastly, predictors of transitions will be explored as this may help to tailor strategies to those at highest risk of a poor outcome.

## Materials and Methods

### *Study Design*

Data were derived from four waves of NEMESIS-2, a prospective psychiatric epidemiological survey in the general Dutch population. Baseline data ( $T_0$ ) were collected from November 2007 to

July 2009. A multistage, stratified, random sampling procedure of households was applied, with one respondent (aged 18–64), randomly selected in each household, resulting in a total sample of 6,646 adults (response rate 65.1%; average interview duration: 95 min). The face-to-face interviews were computer-assisted and were held at the respondent's home. This sample was nationally representative, although younger subjects were somewhat under-represented [25].

All  $T_0$  respondents were approached for follow-up ( $T_1$ ), 3 years after  $T_0$ . Of these, 5,303 persons were reinterviewed (response rate 80.4%; duration: 84 min). All  $T_1$  respondents were approached for a second follow-up ( $T_2$ ), 3 years after  $T_1$ ; 4,618 persons were reinterviewed (response rate 87.8%; duration: 83 min). At third follow-up ( $T_3$ ), 3 years after  $T_2$ , 4,007 persons were reinterviewed (response rate 87.7%; duration: 101 min). Attrition between  $T_0$  and  $T_3$  was not significantly associated with any 12-month mental disorder assessed in the study at  $T_0$  after controlling for sociodemographic characteristics [26].

The study was approved by a medical ethics committee. After receiving information about the study aims, respondents provided written informed consent at each wave. A more comprehensive description of the design can be found elsewhere [25].

#### Diagnostic Instrument

The Composite International Diagnostic Interview (CIDI) 3.0 was used at all waves to determine alcohol consumption, AUD and DSM-IV internalizing, and drug use disorders. The CIDI is a fully structured, lay-administered interview developed by the WHO, which is used worldwide. Clinical reappraisal interviews show that it has generally good validity for assessing common mental disorders [27].

#### Measures

##### Problematic Alcohol Use Characteristics

**High Average Alcohol Consumption (HAAC).** To determine excessive drinking, we focused on HAAC and not on frequent heavy episodic drinking (HED), which is more youth-specific [9, 10]. Alcohol consumption was assessed with two CIDI questions focusing on the past 12 months: "How often did you usually have at least 1 drink?" and "On the days you drank, about how many drinks did you usually have per day?" Multiplying both answers resulted in a quantity-frequency measure of drinks per week. This also yielded a base for the cut-off for HAAC. HAAC was defined as consuming >14 drinks (standard drink: about 10 g of pure alcohol) weekly for women and >21 for men. This is in line with the Dutch definition of HAAC [28] and this level exceeds most acknowledged low-risk drinking guidelines [29, 30].

**AUD.** DSM-IV alcohol abuse and dependence symptoms were assessed with the CIDI 3.0. Because this instrument also assessed craving, all DSM-5 AUD symptoms were available. A symptom count was generated as well as the presence of a 12-month DSM-5 diagnosis of AUD when at least two of the eleven symptoms were reported, and the problems occurred in the past 12 months.

**Weekly HED.** Defined as consuming 5 or more drinks [31] at least weekly in the past 12 months, in line with the Dutch definition of frequent HED [28], and assessed with the CIDI. Weekly HED was not used to identify the latent states but was included as covariate.

#### Sociodemographic and Other Characteristics

Most of these characteristics were measured at each wave, unless explicitly stated.

**Sociodemographics.** Sex, age, educational level (only assessed at baseline [ $T_0$ ] and  $T_3$ ; baseline information was also used for educational level at  $T_1$  and  $T_2$ ), living without a partner, having no paid job, and household income (only assessed at  $T_0$ ,  $T_2$  and  $T_3$ , missing at  $T_1$ ).

**Vulnerability Characteristics.** Childhood psychological or physical abuse (more than once) or sexual abuse (once or more) before age 16 (only assessed at  $T_0$ ; baseline information was used at all follow-up waves) and number of negative life events in the past 12 months (0–10; [32]).

**Mental Health.** Twelve-month DSM-IV internalizing disorder (major depression, dysthymia, bipolar disorder, panic disorder, agoraphobia, social phobia, specific phobia, generalized anxiety disorder); 12-month DSM-IV drug use disorder (abuse or dependence); and mental functioning (combined SF-36 scales: psychological health, psychological functioning, social functioning, and vitality (0–100; [8, 33])).

**Lifestyle.** Smoking (in the past month) and physical exercise (defined as weekly  $\geq 1$  h of physical exercise/sport in the past 12 months; assessed at  $T_1$ ,  $T_2$  and  $T_3$ , missing at  $T_0$ ).

**Physical Health.** Body mass index (BMI;  $\text{kg}/\text{m}^2$ ), presence of  $\geq 1$  of 17 chronic somatic diseases treated or monitored by a medical doctor in the past 12 months assessed with a standard checklist, and physical functioning (combined SF-36 scales: general health, physical health, physical functioning, and bodily pain (0–100; [8, 33])).

#### Statistical Analyses

To identify latent groups of alcohol use and transitions between groups over time, the present study used time-homogeneous Latent Markov Modelling (LMM). LMM uses data from all waves at the same time to concurrently identify (a) latent states showing distinct patterns of alcohol use while taking into account both excessive drinking and AUD and (b) distinct patterns of transitions represented in latent transition classes ( $N = 6,646$ ; total number of data points: 20,574). The analysis consisted of three steps and the statistical programme Latent GOLD 5.1 was used [34]. In the first step, models with an increasing number of latent states and transition classes were explored and the best fitting model was chosen. The selected model identified four latent states with distinct patterns of alcohol use (see Table 1) and two specific types of transition classes, namely: "stayers" who remain in their original state during all waves, and "movers" with probabilities of a transition from one state to another between any of two consecutive waves. Fit statistics and other considerations in the model selection are described in the online supplementary material (see [www.karger.com/doi/10.1159/000526137](http://www.karger.com/doi/10.1159/000526137)).

In the second step, respondents belonging to different latent states (data of all waves combined) were compared with respect to various covariates measured at the same wave as the state, i.e., problematic alcohol use characteristics and sociodemographics, vulnerability, mental health, lifestyle, and physical health characteristics. Simple bivariate analyses were performed in Latent GOLD 5.1 (bias-adjusted three-step approach with Wald tests to determine significant differences between states [ $p < 0.05$ ]).

Finally, in the third step, "movers" with specific transitions between states were further examined. Using Stata 16.0, two overall

**Table 1.** State indicators and problematic alcohol use characteristics for the total population and by latent state, in percentages or means

	Total	States				Wald	p value
		1. No HAAC, no AUD, %/mean	2. HAAC, no AUD, %/mean	3. No HAAC, often AUD, %/mean	4. HAAC and AUD, %/mean		
State size, %	–	91.2	5.0	2.8	1.0	–	–
State indicators (dichotomous)							
HAAC	5.5	0.6	80.8	0.1	97.6		
AUD	2.5	0.5	6.0	36.1	81.3		
Problematic alcohol use characteristics							
Weekly drinks (mean), <i>n</i>	5.7	3.8	31.9	10.5	43.5	2,077.76	<0.001
AUD symptoms (mean), <i>n</i>	0.1	0.003	0.06	2.3	4.9	193.69	<0.001
Weekly HED	12.5	6.9	73.0	60.9	93.1	1,167.75	<0.001
AUD symptoms							
Larger quantities or longer than intended	7.9	4.0	19.9	87.5	98.2	515.82	<0.001
Impaired control over use	2.1	0.3	5.7	34.1	65.1	359.77	<0.001
Great deal of time spent obtaining, using or recovering	1.2	0.4	1.3	17.2	41.4	380.82	<0.001
Failure to fulfil major role obligations	2.9	1.4	5.1	35.7	44.0	583.14	<0.001
Continued use despite social or interpersonal problems	0.9	0.3	2.3	8.5	21.2	246.22	<0.001
Important activities given up or reduced	0.9	0.2	0.6	14.5	32.5	247.07	<0.001
Hazardous use	4.2	2.2	8.5	46.4	51.1	568.76	<0.001
Use despite physical or psychological harm	1.0	0.2	2.4	13.4	36.4	283.10	<0.001
Tolerance	1.6	0.6	2.7	22.3	37.8	479.95	<0.001
Withdrawal	1.0	0.4	2.7	8.3	34.2	383.81	<0.001
Craving	1.8	0.5	5.2	20.6	51.6	456.92	<0.001

Total *N* = 6,646. Number data points: 20,574 (except number of weekly drinks with 20,539 data points and weekly HED with 20,569 data points).

transition patterns were constructed to ensure adequate power. These patterns were defined based on a clear increase or decrease of the problematic alcohol use, that is (a) development of problematic alcohol use among those without problems at a prior wave and (b) decrease of problematic alcohol use among those with the most severe problems at a prior wave. We then explored whether sociodemographic, lifestyle, vulnerability, mental and physical health characteristics measured at the wave preceding the transition predicted these patterns using bivariate logistic regression analyses ( $p < 0.05$ ). To avoid discarding potentially interesting correlations prematurely in these exploratory analyses (type-II errors), no adjustments for multiple testing were made.

## Results

### Description of the Four Latent States

State 1 (*no HAAC, no AUD*) contained 91% of the population. The proportions of HAAC and AUD were both very low in this state (each less than 1%; Table 1). Also, people in this state reported the lowest number of weekly drinks and AUD symptoms (on average 4 drinks and 0.003 symptoms, respectively) as well as a low rate of weekly HED (7%) (see Table 1). State 2 (*HAAC, no AUD*) was present in 5% of the population. A high proportion

of respondents in this state reported HAAC (81%) and a low proportion reported AUD (6%). On average they reported 32 weekly drinks, almost no AUD symptoms (0.06) and almost three quarters reported weekly HED (73%). State 3 (*no HAAC, often AUD*) was present in 3% of the population. In this state, no respondents reported HAAC (0%) and a moderate proportion reported AUD (36%) with the following AUD symptoms being most frequently reported: large quantities or longer alcohol use than intended (88%), hazardous use of alcohol (46%), failures to fulfil major role obligations (36%), and impaired control over alcohol use (34%). They reported on average 11 weekly drinks, 2.3 AUD symptoms and 61% reported weekly HED. Finally, state 4 (*HAAC and AUD*) was present in 1% of the population. Here, high proportions of respondents reported HAAC (98%) and AUD (81%) and in this state the highest number of weekly drinks and AUD symptoms were reported (44 drinks and 4.9 symptoms, respectively) as well as a high rate of weekly HED (93%). Frequently reported symptoms were larger quantities or longer than intended consumption (98%), impaired control over use (65%), craving (52%), and hazardous use (51%).

**Table 2.** Sociodemographic and other characteristics for the total population and by latent state, in percentages or means

	Total, %/mean	States 1. No HAAC, no AUD, %/mean	2. HAAC, no AUD, %/mean	3. No HAAC, often AUD, %/mean	4. HAAC and AUD, %/mean	Wald	<i>p</i> value
<i>Sociodemographics</i>							
Male sex	44.7	42.9	56.4	78.2	61.8	47.20	<0.001
Age (mean)	48.52	48.59	54.52	36.45	44.50	148.87	<0.001
Educational level							
Primary	4.3	4.4	4.4	1.9	6.2	36.06	<0.001
Lower secondary	26.2	26.0	36.4	13.7	30.5		
Higher secondary	32.0	31.7	33.7	38.7	29.1		
Higher professional, university	37.5	37.9	25.6	45.8	34.2		
Living without a partner	29.2	27.3	40.0	59.4	69.9	98.73	<0.001
No paid job	29.2	28.7	42.5	19.0	34.9	41.77	<0.001
Income							
Low	25.2	23.9	34.5	44.1	46.0	60.19	<0.001
Middle	41.9	42.3	43.3	30.7	28.7		
High	32.9	33.8	22.2	25.3	25.3		
<i>Lifestyle</i>							
Smoking	25.7	23.1	53.0	50.4	54.8	191.02	<0.001
Physical exercise	61.3	61.9	46.8	69.9	50.1	35.68	<0.001
<i>Vulnerability factors</i>							
Childhood abuse	28.6	27.4	37.8	44.0	53.2	38.12	<0.001
Negative life events (mean)	0.72	0.70	0.83	1.00	1.09	48.88	<0.001
<i>Mental health</i>							
Internalizing disorder	10.8	10.0	12.6	24.8	43.7	129.98	<0.001
Drug use disorder	0.9	0.7	0.3	5.4	10.4	109.94	<0.001
Mental functioning (mean)		84.10	83.78	77.60	71.45	46.57	<0.001
<i>Physical health</i>							
BMI	25.59	25.64	25.24	24.78	25.42	6.59	0.09
Somatic comorbidity	26.5	26.8	27.9	14.0	28.3	12.31	<0.01
Physical functioning (mean)	82.37	82.52	80.61	83.10	75.73	17.44	<0.001

Total *N* = 6,646. Number data points: HAAC = 20,539; household income = 14,051; smoking = 20,431; physical exercise = 13,892; childhood abuse = 20,233; negative life events = 20,434; mental functioning = 20,571; BMI = 20,510; somatic comorbidity = 20,434; physical functioning = 20,573. For other characteristics, there are no missing data (i.e., 20,574 data points). HAAC, high average alcohol consumption; AUD, DSM-5 alcohol use disorder.

The four latent states significantly differed on all covariates, except on BMI (Table 2). Members of the non-problematic *no HAAC, no AUD* state were characterized by the lowest proportion of males (43%) and living without a partner (27%) and the members of this latent group most often had a high income (34%). Members of the *HAAC, no AUD* state had the highest mean age (55 years), and most often reported a low educational level (41% primary or lower secondary) and having no paid job (43%). Members of the *no HAAC, often AUD* state were most often male (78%) and had a high educational level (46%). They also had the lowest average age (36 years). Finally,

members of the most problematic *HAAC and AUD* state most often lived without a partner (70%) and had the lowest level of income (46%). They also frequently were male (62%) and had no paid job (35%).

The *no HAAC, no AUD* state had the lowest proportions of adults with unhealthy lifestyles, and vulnerability and mental ill-health characteristics. On the other end of the spectrum were adults with the *HAAC and AUD* state, who had the highest proportions for most of these characteristics as well as for physical ill-health. The two states *HAAC, no AUD* and *no HAAC, often AUD* appeared to be in the middle. The *HAAC, no AUD* state contained

**Table 3.** Latent transitions between two consecutive waves for the mover class of the 4-state mover-stayer model (%)

State at time T	State at time T + 1			
	1. No HAAC, no AUD	2. HAAC, no AUD	3. No HAAC, often AUD	4. HAAC and AUD
1. No HAAC, no AUD	83.7	14.6	0.3	1.5
2. HAAC, no AUD	49.0	43.4	7.3	0.3
3. No HAAC, often AUD	16.0	7.7	59.0	17.3
4. HAAC and AUD	10.8	2.4	49.0	37.9

HAAC, high average alcohol consumption; AUD, DSM-5 alcohol use disorder.

higher proportions of adults with unhealthy lifestyles and physical ill-health than *no HAAC, often AUD*, but lower proportions of adults with vulnerability and mental ill-health characteristics.

#### Description of the Two Latent Transition Classes

The population was divided into two transition classes. Eighty-seven percent remained in their original state during all waves (i.e., 9-year stability) and were called “stayers,” 13% of the population were “movers.” Almost all stayers (97%) were without problematic alcohol use (*no HAAC, no AUD*).

As “movers” have a nonzero probability of transition during *any* of the follow-up waves, increase, decline, and stability between two consecutive waves can be observed within the mover class. Table 3 shows transition probabilities within this mover class between two consecutive waves. The state without problematic alcohol use (*no HAAC, no AUD*) was associated with the highest 3-year stability (84% stayed in this non problematic alcohol use group), whereas the most severe state (*HAAC and AUD*) was associated with the lowest stability (38% stayed in this most problematic alcohol use group). Yet, people from this latter state mostly transitioned to another state of problematic alcohol use (almost half to *no HAAC, often AUD*) and quite rarely (11%) to the state of nonproblematic alcohol use. Regarding people in the state *HAAC, no AUD*, about half of them remained in this state or transitioned to another problematic alcohol use state. People in the state *no HAAC, often AUD* mainly remained in this state (59%) or transitioned to another problematic alcohol use state, i.e., *HAAC and AUD* (17%).

Finally, we explored the predictive effect of many sociodemographic, lifestyle, vulnerability, and mental and physical health characteristics for transitions with a clear-cut increase or decrease in problematic alcohol use (Ta-

ble 4). First, transition from *no HAAC, no AUD* to any other state, i.e., increased drinking and/or alcohol use problems, was examined. This negative transition was significantly associated only with lack of prior physical exercise. Second, the transition from *HAAC and AUD* to any other state, i.e., reduced drinking and/or alcohol use problems was examined. This positive transition was significantly associated with prior physical exercise and better mental and physical functioning. Comorbid internalizing disorder and higher number of negative life events lowered the odds of this positive transition.

#### Discussion

First, building on prior research [15–17], the present population-based prospective study identified four meaningful empirical groups using latent class analyses with two aspects of problematic alcohol use: HAAC and AUD. Second, thanks to the uniquely long follow-up period of 9 years [35], we were the first to demonstrate that the vast majority of the population is long-term without problematic alcohol use. Third, by examining a broader range of characteristics than the more frequently included demographics (most frequently age and gender) and alcohol characteristics [35] in previous research, we could point to a possible role for physical exercise and mental ill-health in transitions toward problematic alcohol use.

At any time-point, 9% of the adults belonged to one of three groups with some kind of problematic alcohol use, including a *no HAAC, often AUD* group. This group was not previously detected with latent class analyses in selective samples [15–17], but its presence was hypothesized based on previous population-based findings showing that not all people with alcohol dependence drink excessively [13]. Further characterization of this group points

**Table 4.** Sociodemographic and other characteristics associated with transitions with a clear increase or decrease in problematic alcohol use examined with binary logistic regression analyses resulting in Odds Ratios (OR) with 95% CI

	Transition from state 1 (increase of problematic alcohol use), OR (95% CI)	Transition from state 4 (reduction of problematic alcohol use), OR (95% CI)
<i>Sociodemographics</i>		
Male sex	0.85 (0.58, 1.23)	0.96 (0.43, 2.13)
Age (mean)	1.00 (0.99, 1.02)	0.98 (0.96, 1.01)
Educational level		
Primary	Ref	Ref
Lower secondary	0.93 (0.35, 2.51)	0.28 (0.03, 2.82)
Higher secondary	0.74 (0.27, 2.02)	0.50 (0.05, 4.98)
Higher professional, university	0.75 (0.28, 2.02)	0.46 (0.05, 4.56)
Living without a partner	1.08 (0.72, 1.60)	0.65 (0.29, 1.48)
No paid job	1.05 (0.70, 1.57)	0.59 (0.26, 1.34)
Income		
Low	Ref	Ref
Middle	1.48 (0.83, 2.65)	1.11 (0.39, 3.14)
High	0.97 (0.51, 1.84)	1.49 (0.42, 5.19)
<i>Lifestyle</i>		
Smoking	1.10 (0.76, 1.61)	1.15 (0.54, 2.47)
Physical exercise	0.64* (0.41, 0.99)	3.84* (1.24, 11.87)
<i>Vulnerability factors</i>		
Childhood abuse	1.18 (0.78, 1.77)	0.63 (0.29, 1.35)
Negative life events (mean)	1.16 (0.97, 1.40)	0.64* (0.45, 0.90)
<i>Mental health</i>		
Internalizing disorder	1.40 (0.82, 2.39)	0.30** (0.14, 0.67)
Drug use disorder	1.00 (1.00, 1.00)	1.65 (0.41, 6.60)
Mental functioning (mean)	1.00 (0.98, 1.01)	1.02* (1.00, 1.04)
<i>Physical health</i>		
BMI	1.03 (0.98, 1.08)	0.95 (0.86, 1.05)
Somatic comorbidity	1.01 (0.65, 1.55)	1.11 (0.47, 2.61)
Physical functioning (mean)	1.00 (0.99, 1.01)	1.04** (1.01, 1.06)
CI, confidence intervals. * $p < 0.05$ ; ** $p < 0.01$ .		

to highly educated young males who perceive AUD symptoms (on average 2) even without excessive drinking (on average 11 drinks weekly). Although more than half of them reported weekly HED, this rate was lower than in the other problematic alcohol use groups. Possibly, people in this group are easily concerned or quickly experience negative effects from their drinking behaviour, or they may have high demands in their professional and personal lives which do not mix with even relatively low levels of alcohol use. This latter explanation is supported by the relatively high frequency of the symptoms “use in hazardous situations” and “failure to fulfil major role obligations.” Furthermore, transition analyses showed that people with AUD-only frequently remained within this

group (59%) or moved to the most severe – HAAC and AUD – group (17%), and only a minority (16%) transitioned to a group of nonproblematic alcohol use. Adequate detection and support for people in this group with serious risks seems desirable. Regarding screening, this implies attention to alcohol-related problems and not only alcohol consumption especially in highly educated young males, for example, using an instrument such as the five-shot [36].

Additionally, a group with frequent HAAC, but infrequent AUD was identified. This group was previously detected, but in contrast to findings among elderly [17] and workers [16], we did not find that high income was associated with this group in our general population sample.

This group mainly consisted of older excessive drinkers who experience on average less than one AUD symptom despite substantial levels of alcohol use (on average 32 drinks weekly). Possibly, interference from their alcohol use is quite low because they relatively often have no paid job and therefore may experience fewer problems. Post hoc analyses completed the picture and showed that people in this group were relatively often retired. However, other unhealthy lifestyles and physical ill-health were frequently present. Moreover, the excessive alcohol use was persistent in almost half of the people in this group and some developed AUD over time. This supports the idea that even in the absence of an AUD diagnosis, strategies that target lower levels of alcohol consumption, such as promoting knowledge about population consumption levels and encouraging drinkers to take pride in lowering that level [30], are recommended.

In line with previous research [8, 17], we observed that the small group with high proportions of both HAAC and AUD had the worst mental and physical health. As in previous studies applying latent transition analyses [15, 21], we observed that they were the most likely to experience a transition and that these transitions mostly occurred toward an improved, but still problematic level of alcohol use (i.e., with either HAAC or AUD, most often to *no HAAC, often AUD*) and only rarely to a status of non-problematic alcohol use. This is also in line with accumulating population-based findings [35, 37–40] that a significant proportion of remitted AUD individuals continue to drink. Further exploration of predictors of a transition from this most problematic group revealed no important role for demographic characteristics supporting previous findings showing that persistency over time is relatively stable over age [21, 35, 41] and that gender is not associated with AUD remission [35, 42]. We found that physical exercise was related with a decline of problematic alcohol use. This is in line with well-documented findings from clinical research that exercise has a positive effect on anxiety, depression, and craving [43]. Another finding was that those in *HAAC and AUD* but with an otherwise healthy lifestyle or good mental or physical health seemed to be able to remit from this state. This concurs with previous research showing that remission from 12-month AUD was associated with absence of mental comorbidity [37]. This could indicate that interventions, including secondary prevention strategies, should pay extra attention to those with other adverse characteristics besides problematic alcohol use. Yet, replication of these exploratory findings is warranted.

Lastly, 91% of the present population-based sample was without any problematic alcohol use and the vast majority of this group remained that way over the 9-year follow-up period, although a number developed some kind of problematic alcohol use in a 3-year period (most often *HAAC, no AUD*). Exploratory analyses among these movers were performed to predict transition from non-problematic alcohol use toward any of the other states. Notably, only lack of physical exercise was associated with this negative transition. Previous research on onset of problem drinking or AUD observed associations with several characteristics such as younger age, male gender, and partner status [23, 24]. It is difficult to explain why such associations are not found in the current study. Possibly this is because we did not only include first-onset but also recurrence of problematic alcohol use. Another explanation could be that the analyses were not limited to onset of AUD but also included onset of excessive drinking. Regarding physical exercise, previous research has pointed to lack of physical exercise as an important covariate of problematic alcohol use and mental ill-health [44–46], but there is also evidence that higher levels of physical exercise are related to higher alcohol consumption levels [47]. Therefore, the relationship between lack of physical exercise and onset of aspects of problematic alcohol use should be further addressed in future research.

#### *Strengths and Limitations*

Our study has important strengths, including the large population-based sample of adults, the prospective design covering 3-, 6-, and 9-year follow-up waves, the use of a standardized diagnostic instrument (CIDI) to assess alcohol consumption and presence of AUD and other mental disorders, and the possibility to explore a wide range of potential associated characteristics and predictors. Yet, some limitations merit discussion.

As alcohol consumption and AUD symptoms were based on self-report, recall bias, and social desirability could have influenced the results. People may have difficulties remembering the amounts and frequencies of alcohol consumption in an average week or they may have been reluctant to report problems with alcohol use. This may have resulted in a biased estimate, most likely an underestimation of excessive alcohol use and AUD symptoms [43] and subsequently an underestimation of the prevalence of problematic alcohol use groups. Second, the DSM-5 clustering criterion (2+ symptoms in the same 12-month period) was not assessed, and therefore, we used a symptom count to generate the AUD diagnosis

[37, 48]. This may have resulted in an overestimation of AUD. However, the bias is likely to be limited because the presence of multiple symptoms has been associated with poor outcomes, regardless of 12-month clustering [49]. Finally, the number of subjects with specific transition patterns was small, resulting in limited power in the explorative analyses where we tried to predict these transitions. Moreover, we could only examine two general transition patterns, not transitions between specific states. Replication of these findings in studies with even larger samples and further characterization of these transitions is therefore warranted.

## Conclusion

This general-population study with many data points found evidence for four alcohol use groups based on excessive drinking and AUD: one nonproblematic and three problematic alcohol use groups. Of note is the identification of an AUD-only group, i.e., an AUD group without excessive drinking. This underscores the need to explicitly address alcohol-related problems in screening besides alcohol consumption. We also found that, in 3-year periods, the groups with excessive drinking and/or AUD were quite stable or shifts to other problematic alcohol use groups occurred. This suggests that all problematic groups may benefit from interventions, preferably tailored to the intensity of alcohol use or with a focus on specific AUD symptoms. Lastly, our explorative analyses suggest that lack of physical exercise seems to increase the risk of problematic alcohol use and to decrease the likelihood of changing from the most problematic group over time. Additional studies are needed to confirm this potentially important role of physical exercise.

## Statement of Ethics

The study was approved by a medical ethics committee (the Medical Ethics Review Committee for Institutions on Mental Health Care (METIGG) Zuid, Tilburg, The Netherlands), approval number NL18210.097.07. After receiving information about the study aims, respondents provided written informed consent at each wave.

## Conflict of Interest Statement

The authors declare no conflict of interest.

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## Author Contributions

Margreet ten Have and Ron de Graaf obtained funding for this manuscript. Margreet ten Have, Ron de Graaf, Saskia van Dorselaer, and Marlous Tuithof contributed to acquisition of data. Marlous Tuithof undertook the analysis with supervision of Jeroen Kornelis Vermunt. Marlous Tuithof wrote the first draft of the manuscript. Marlous Tuithof, Margreet ten Have, Saskia van Dorselaer, Derek de Beurs, Wim van den Brink, Ron de Graaf, and Jeroen Kornelis Vermunt contributed to the conception, design and interpretation of analysis for this manuscript, as well as its critical revision. All the authors contributed to and have approved the final manuscript.

## Data Availability Statement

The data on which this manuscript is based are not publicly available. However, data from NEMESIS-2 are available upon request. The Dutch ministry of health financed the data and the agreement is that these data can be used freely under certain restrictions and always under the supervision of the Principal Investigator (PI) of the study. Thus, some access restrictions do apply to the data. The PI of the study (Margreet ten Have; email mhave@trimbos.nl) can, at all times, be contacted to request data.

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