Maria Portman

Risk factors for drunk driving

Results from a long-term study in Uusimaa in Finland 1990-2008

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RISK FACTORS FOR DRUNK DRIVING

Results from a long-term study in Uusimaa in Finland 1990-2008

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Abstract

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In the 1990s, the prevalence in road traffic of drivers, whose blood alcohol concentration was positive, but below the legal limit 0.50 ‰, i.e. 'had been drinking' varied between 0.34% and 0.50%, which means that one out of every 200 to 300 drivers. The prevalence of drunk driving was 0.2%, meaning that one out of every 500 drivers was over the legal limit. The prevalence of drivers who 'had been drinking' began to climb in the early 2000s and peaked at 1.11% in 2005, i.e. one out of every 90 drivers. This increase was mainly caused by drivers whose blood alcohol level was less than 0.20 ‰.

Also, the percentage of women, of drivers over the age of 55 and of drivers driving their own cars among the drivers who 'had been drinking' increased during this time. In the following years, the prevalence of drivers who 'had been drinking' began to fall, and it has since stabilized at approximately the level where it was in the early 2000s. This is, however, about one and a half time higher than in the 1990s. In2008, about one out of every 170 drivers 'had been drinking'. The prevalence of drunk drivers in road traffic, by comparison, has not changed over time. During the study period 1990–2008 altogether 542 495 drivers were tested. Of them 1241 were drunk drivers and 3087 drivers, who 'had been drinking'.

Sober drivers, drivers who 'had been drinking' and drunk drivers differ in their profiles in terms of gender and marital status. Men are about three times as likely as women to 'had been drinking' or to be over the legal limit when driving. Divorcees outnumbered married persons. Age, on the other hand, did not correlate with whether a driver 'had been drinking' or was drunk. In comparing drivers who 'had been drinking' and drunk drivers, it was found that driving without a driver's license carried a fivefold risk of the driver belonging to the former group.In the profiles of drivers who 'had been drinking' with blood alcohol levels of under 0.20 ‰ on the one hand and over 0.20 ‰ on the other, more similarities than differences were found.Both groups were similar in profile in terms of gender and marital status.The percentages of men, of divorcees and of unemployed persons were considerably lower in the group of drivers who 'had been drinking' with a blood alcohol level of over 0.20 ‰ than in the group of drunk drivers. It is not a valid conclusion to deduce from this profile that a driver who 'had been drinking' and had a blood alcohol level of over 0.20 ‰ was a potential drunk driver.

Risk factors for driving as a driver who 'had been drinking' or as a drunk driver were found in the driver's profile, driving history, the blood alcohol level and in high levels for two indicators of heavy alcohol use. The risk of drunk driving for women was less than one fifth of that for men. Divorces and widow(er)s had a substantially higher risk of being caught drunk driving than married drivers. It was estimated that about half of all drunk drivers are repeat offenders. The risk of a repeat offender being caught drunk driving again was 3.3 to 5 times higher than for a first offender. If the blood alcohol level was over 1.20 ‰, the risk of recidivism was 2.5 times higher than for other drunk drivers.

In subjects were the mathematical model of the two indicators for heavy alcohol use, γ–glutamyl-transferase (GGT) and carbohydrate deficient transferrin (CDT), showed high levels, the risk for recidivism was 1.4 times higher than for normal levels.

The risk of being caught is low, even though drunk drivers themselves consider it high or very high. It was estimated that a drunk driver can drive while over the legal limit on about 220 occasions before being caught.

The extensive time series and material collected from roadside testing in Uusimaa form a dataset which is unique worldwide. The study concept makes it possible to collect information in order to evaluate and estimate the influence and effectiveness of preventive countermeasures. The study concept should be developed and revised to suit current circumstances better while maintaining compatibility with earlier findings.

In substance abuse assessment in health care, attention should be paid more effectively to a person's overall life situation in order to chart the risk factors for drunk driving. Out of technical means of preventing drunk driving, the most efficient would be to expand the use of alcolocks through national legislation. The findings of the present study support an obligatory use of alcolocks for recidivists regardless the blood alcohol concentration and also for those, whose blood alcohol concentration is over the limit for aggravated drunk driving (1.20 ‰) already at the first time of being caught.

Tiivistelmä

Maria Portman. Risk factors for drunk driving. Results from a long-term study in Uusimaa in Finland 1990-2008. Terveyden ja hyvinvoinnin laitos (THL), Raportti 8/2014. 67 sivua. Helsinki 2014.
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Maistelleiden osuus liikennevirrassa vaihteli 1990–luvulla 0,34–0,50 % välillä, joka tarkoittaa sitä että noin joka 200. –300. kuljettaja oli maistellut. Rattijuoppojen osuus oli tällöin 0,2 % tasolla eli noin joka 500. kuljettaja oli rattijuoppo. Maistelleiden osuus lähti nousuun 2000–luvun alussa ja oli korkeimmillaan 1,11 % vuonna 2005, jolloin noin joka 90. kuljettaja oli maistellut. Nousun aiheuttivat pääasiallisesti sellaiset kuljettajat, joiden alkoholipitoisuus oli alle 0,20 ‰. Lisäksi maistelleissa oli tällöin enemmän naisia, yli 55 vuotiaita ja omalla autolla ajaneita. Maistelleiden osuus lähti laskuun seuraavina vuosina ja on sen jälkeen asettunut 2000–luvun alun tasolle. Taso on noin puolitoista kertaa korkeampi verrattuna 1990–lukuun. Vuonna 2008 noin joka 170 kuljettaja oli maistellut. Rattijuoppojen osuudessa ei ole tapahtunut muutoksia ajan suhteen. Vuosina 1990–2008 testattiin yhteensä 542 495 kuljettajaa. Heistä 1241 oli rattijuoppoja ja 3087 maistelleita.

Raitis kuljettaja, maistellut ja rattijuoppo eroavat profiililtaan toisistaan sekä sukupuolen että siviilisäädyn osalta. Miesten osuus oli noin kolme kertaa suurempi kuin naisten sekä maistelleissa että rattijuopoissa. Myös eronneita oli enemmän kuin naimisissa olevia. Ikä ei sen sijaan liittynyt siihen, ajoiko henkilö maistelleena tai rattijuoppona. Verrattaessa maistelleita ja rattijuoppoja todettiin, että ajokortitta ajo ennusti viisinkertaistaa riskiä kuulua jälkimmäiseen ryhmään. Alle 0,20 ‰:n maistelleiden ja yli 0,20 ‰:n maistelleiden profiilissa todettiin enemmän yhtäläisyyksiä kuin eroja. Sukupuolen ja siviilisäädyn suhteen molempien ryhmien profiilit olivat samankaltaiset. Verrattuna rattijuoppoihin yli 0,20 ‰:n maistelleiden ryhmässä miesten, eronneiden ja työttömien osuudet olivat selkeästi alemmat. Profiilin perusteella ei voida päätellä, että yli 0,20 ‰:n maistellut olisi potentiaalinen rattijuoppo.

Riskitekijöitä maistelleena tai rattijuoppona ajamiselle todettiin olevan sekä kuljettajan profiilissa, ajohistoriassa, promillearvossa että alkoholin suurkulutuksen osoittimien tasossa veressä. Naisten rattijuopumusriski oli alle viidesosa miesten riskistä. Eronneilla ja leskillä oli selvästi korkeampi riski jäädä kiinni rattijuopumuksesta kuin naimisissa olevilla. Arviolta noin puolet rattijuopoista on uusijoita. Uusijan riski syyllistyä taas uudelleen rattijuopumukseen on 3,3 – 5 -kertainen verrattuna ensikertalaiseen. Yli 1,20 ‰ rattijuopumukseen syyllistyneiden uusimisriski on 2,5 -kertainen muihin rattijuoppoihin verrattuna.

Mikäli alkoholin suurkulutuksen osoittimien γ–glutamyylitransferaasin (GGT) ja niukkahiilihydraattinen transferriinin (CDT) matemaattinen malli todettiin olevan koholla, riski rattijuopumuksen uusimiselle oli 1,4-kertainen verrattuna normaalitasoon.

Yleisellä tasolla on kiinnijoutumisriski pieni vaikka rattijuoppo itse arvioi riskin olevan hyvin suuri tai suuri. Voidaan arvioida, että rattijuoppo voi ajaa noin 220 kertaa humalassa ennen kiinnijäämistään.

Uudenmaan ratsiatutkimuksen pitkä aikasarja ja kerätty aineisto ovat kansainvälisesti ainutlaatuiset. Ratsiatutkimus mahdollistaa kattavien tutkimustietojen hankkimisen, joilla pystytään seuraamaan ja arvioimaan ennaltaehkäisevien toimenpiteiden vaikutusta ja tehokkuutta. Tutkimuskonseptia tulisi kehittää ja uudistaa nykyisiin olosuhteisiin paremmin sopivaksi pyrkien kuitenkin säilyttämään vertailukelpoisuus.

Terveydenhuollon päihdearvioinnissa tulisi kiinnittää entistä tehokkaammin huomiota henkilön elämäntilanteeseen kokonaisvaltaisesti rattijuopumuksen riskitekijöiden selvittämiseksi. Teknisin keinoin rattijuopumusta vähennetään tehokkaimmin muun muassa laajentamalla alkolukon käyttöä kansallisella lainsäädännöllä. Tämän raportin tulokset puoltavat alkolukon pakollista käyttöönottoa rattijuopumuksen uusijoille promillearvosta huolimatta sekä niille, joiden veren alkoholipitoisuus ylittää törkeän rattijuopumuksen rajan (1,20 ‰) jo ensimmäisellä kiinnijäämisellä.

Sammandrag

Maria Portman. Risk factors for drunk driving. Results from a long-term study in Uusimaa in Finland 1990-2008. Institutet för hälsa och välfärd. Rapport 8/2014. 67 sidor. Helsingfors, Finland 2014.
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Prevalensen i trafikströmmen av lindrigt alkoholpåverkade förare (positiv blodalkoholkoncentration, men under straffgränsen på 0,50 ‰) varierade mellan 0,34 och 0,50 % under 1990-talet, vilket innebär i genomsnitt en av 200-300 förare. Prevalensen av rattfylleri under samma tid var ungefär 0,2 %, vilket innebär att i genomsnitt en av 500 förare var rattfull. Prevalensen av lindrigt alkoholpåverkade förare ökade i början av 2000–talet och var som högst år 2005 (1,11 %), dvs i genomsnitt en av 90 förare. Ökningen gällde huvudsakligen förare med ett alkoholvärde under 0,20 ‰. Bland dem fanns fler kvinnor, personer över 55 år och förare med egen bil . Prevalensen minskade under de följande åren och stannade på samma nivå som i början av 2000–talet. Nivån är cirka 1,5 gånger högre än på 1990–talet. År 2008 var i genomsnitt en av 170 förare lindrigt alkoholpåverkad. Prevalensen av rattfylleri har inte förändrats under åren. Under åren 1990–2008 testades totalt 542 495 förare. Av dem var 1241 rattfylleristerna (över 0,50 ‰) och 3087 lindrigt alkoholpåverkade (under 0,50 ‰).

Nyktra och lindrigt alkoholpåverkade förare samt rattfyllerister har olika profiler i fråga om kön och civilstånd. Av de lindrigt alkoholpåverkade förarna och rattfylleristerna var andelen män cirka tre gånger större än andelen kvinnor. Andelen frånskilda var större än andelen gifta. Någon ålderskorrelation kunde inte iakttas. En jämförelse mellan gruppen lindrigt alkoholpåverkade och rattfyllerister visade att avsaknaden av körkort var fem gånger vanligare i den senare gruppen. Bland de lindrigt alkoholpåverkade med en blodalkoholhalt över och under 0,20 ‰ var likheterna fler än skillnaderna. Vardera gruppen hade likartade profiler i fråga om kön och civilstånd. Jämfört med rattfyllerister var andelen män, frånskilda och arbetslösa betydligt mindre i gruppen 0,20–0,49 ‰. På basis av profilen kan man inte avgöra om en lindrigt alkoholpåverkad förare i gruppen 0,20–0,49 ‰ är en potentiell rattfyllerist.

Riskfaktorer för att köra lindrigt alkoholpåverkad eller som rattfyllerist konstaterades såväl i förarens profil, körhistoria, promillevärdet och nivån av biokemiska alkoholmarkörer i blodet. Bland kvinnor utgör risken för rattfylleri mindre än en femtedel av risken bland män. Frånskilda och änklingar/änkor har en klart högre risk att åka fast för rattfylleri än gifta personer. Uppskattningsvis omkring hälften av rattfylleristerna är återfallsrattfyllerister. Risken för en återfallsrattfyllerist att på nytt göra sig skyldig till rattfylleri är 3,3–5 gånger större än för en person som första gång-

en gör sig skyldig till rattfylleri. Ifall förarens promillevärde är över 1,20 ‰, är risken för återfall 2,5 gånger högre än vid lägre promillevärden.

Om en matematisk modell av de biokemiska alkoholmarkörerna γ–Glutamyltransferas (GGT) och kolhydratfattigt transferrin (CDT; carbohydrate deficient transferrin) var förhöjt i blodet så är risken för återfall i rattfylleri 1,4-faldig jämfört med normalvärden.

På allmän nivå är risken för att åka fast liten, även om rattfylleristerna själv upplever risken som mycket stor eller stor. Uppskattningsvis kan en rattfyllerist i genomsnitt köra ca 220 gånger innan han eller hon åker fast.

Den långa tidsserien och det omfattande materialet i razziaundersökningen i Nyland är internationellt unika. Razziaundersökningen möjliggör insamlande av omfattande material som kan användas för uppföljning och för bedömning av de förebyggande åtgärdernas inverkan och effektivitet. Det är viktigt att bibehålla jämförbarheten då man utvecklar och förnyar undersökningsmetoderna.

Vid bedömningen av missbruk inom hälso- och sjukvården bör allt mer uppmärksamhet fästas vid personens livssituation för att utreda riskfaktorerna för rattfylleri. De effektivaste tekniska metoderna för att minska rattfylleri är bland annat att lagstiftningsvägen utvidga användningen av alkolås. Resultaten från föreliggande rapport stöder obligatorisk användning av alkolås för alla återfallsrattfyllerister oberoende av blodalkoholkoncentrationen och för dem, som har en blodalkoholkoncentration ≥ 1.20 ‰ redan vid första gången de åker fast.

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List of original papers

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II M. Portman, A. Penttila, J. Haukka, S. Rajalin, C.J.P. Eriksson, T. Gunnar, H. Koskimaa, K. Kuoppasalmi, Profile of a drunk driver and risk factors for drunk driving. Findings in roadside testing in the province of Uusimaa in Finland 1990–2008, Forensic Sci. Int. 231 (2013) 20–27.

III M. Portman, A. Penttilä, J. Haukka, P. Eriksson, T. Gunnar, K. Kuoppasalmi, et al., Rattijuopon profiili ja uusimisen riskitekijät. Tuloksia rattijuopumuksen esiintyvyydestä ja kehityksestä Uudenmaan ratsiatutkimuksesta vuosina 1990–2008. Summary in English. www.lintu.info. 1/2011 (2011) 1-80.

IV M. Portman, A. Penttilä, J. Haukka, P. Eriksson, T. Gunnar, K. Kuoppasalmi, et al., Maistelleet liikenteessä. Tuloksia Uudenmaan ratsiatutkimuksesta 1990–2008. Summary in English, www.lintu.info. 4/2012 (2012) 1-82.

Abbreviations

ALAT	Alanine aminotransferase
ALDH2	Aldehyde dehydrogenase
ASAT	Aspartat aminotransferase
AUDIT	Alcohol Use Disorders Identification Test
BAC	Blood alcohol concentration
CAGE	A questionnaire of alcohol consumption: 1. Have you ever felt you ought to Cut down on your drinking? 2. Have people Annoyed you by criticizing your drinking? 3. Have you ever felt bad or Guilty about your drinking? 4. Have you ever taken a drink first thing in the morning to steady your nerves or get rid of a hangover (Eye-opener)?
CDT	Carbohydrate deficient transferrin
CI	Confidence interval
DRUID	Driving under the influence of drugs, alcohol and medicines
DSM–IV	Diagnostic and Statistical Manual of Mental Disorders
DUI	Driving under the influence
EC	Enzyme Commission
EDAC	Early detection of alcohol consumption
EtG	Ethyl glucuronide
EtS	Ethyl sulfate
EU	European Union
GGT	γ–Glutamyltransferase
5–HIAA	5–Hydroxyindole acetic acid
HPLC	High performance liquid chromatography
HS–GC	Headspace-gas-chromatograph
5–HTOL	5–Hydroxytryptophol
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
IFCC–WG–CDT	Working Group on Standardization of Carbohydrate-deficient Transferrin
IQR	Interquartile range
KEGG	Kyoto Encyclopedia of Genes and Genomes
MAC	MacAndrews Alcoholism Scale
MAO	Monoamine oxidase
MCV	Mean corpuscular volume
OR	Odds ratio
PEth	Phosphatidylethanol
pI	Isoelectric point
RBT	Random breath testing
SD	Standard deviation
SE	Standard error
Tf	Transferrin

1 Introduction

In society it is often demanded that drunk drivers should have more severe punishment. However, effective efforts to prevent drunk driving have not been discussed and evaluated enough. The best results and recommendations, which are based on international research, have not been put efficiently into practice.

Drunk driving is involved in 25 % of fatal traffic accidents in Finland. In 2011 74 persons died and 735 were injured in traffic accidents which involved drunk driving [1]. It has been estimated that the cost of a traffic fatality is 1.9 million euro. A permanent injury costs 1.0 million euro and a temporary injury on average 241 000 euro [2].

The results of the present study show that the profile of a drunk driver has not changed for a long period. About one third of drunk drivers are recidivists and the rate has remained at the same level for 30 years. The risk of being caught has not increased for 30 years. A drunk driver can still drive drunken about 220 occasions before being caught. It is estimated that during 24 hours about 3460 drunk driving cases occur in Uusimaa district.

The study was carried out by a research team, where the National Traffic Police in Helsinki had a key role. The commitment of the National Traffic Police to systematic and professional fieldwork made it possible to achieve results that are both reliable and comparable over the time span. In the study the systematic Random Breath Testing method (RBT) was used. Use of the method requires that police officers are able to ask drivers for a breath test even when there is no suspicion of drunk driving. The RBT surveys measure and follow up the true rate of alcohol use in the traffic flow and cover all types of drivers on a non-selective basis within a specified period. The RBT method was introduced in Finland in 1979.

The main group in the present study was alcohol positive drivers in roadside surveys from a period of eighteen years, 1990–2008. The subjects were drunk drivers (n=1241), i.e. drivers, whose blood alcohol concentration (BAC) was found to be above the legal limit, 0.50 ‰, and drivers, who "had been drinking", (n=3087), but whose BAC remained below 0.50 ‰. Altogether 542 495 drivers were tested during the study period. Two extensive reports have been published in Finnish. The report of drunk drivers was published in 2011 (paper III). The report of drivers, who "had been drinking" was published in 2012 (paper IV).

The design of the study made it possible to investigate further minor groups in respect of level of alcohol biomarkers, risk factors for drunk driving and recidivism. The alcohol biomarkers were γ–glutamyl-transferase (GGT) and carbohydrate deficient transferrin (CDT). The mathematical combination γ–CDT, (= 0.8 x ln GGT + 1.3 x ln CDT), was also evaluated as a risk factor. Retrospective and prospective DUI (driving under influence) recidivism was studied in these minor groups during a time span of 16 years (paper I).

Recidivism has been frequently studied worldwide in the research of drunk driving. Although technical and medical solutions might reduce the problem occasionally, the majority of drunk drivers have not changed their behavior. Recidivism is a remarkable problem not only in society at a general level, but also for the drunk driver at a personal level. Every effort to prevent drunk driving and recidivism should be considered.

Preventive recommendations are presented as a result of the present long-term study. These recommendations are easy to apply both technically, economically and medically. Results of Finnish drunk driving research should be applied to Finnish drunk drivers.

2 Review of the literature

2.1 Alcohol positive drivers

2.1.1 Legislation for drunk driving

The statutory limit for drunk driving in Finland is 0.5 ‰. The act came into force in 1977. The limit is defined as a mass/mass unit (0.053 %, mass/volume, 1.055 kg/l used as the specific weight of whole blood). The limit for aggravated drunk driving is 1.2 ‰ (0.127 %). The corresponding limits for evidential breath samples are 0.22 mg/l and 0.53 mg/l [3].

In most countries in the European Union (EU) the statutory limit is 0.5 ‰. In Sweden, Norway, Estonia and Poland the limit is 0.2 ‰, but in the United Kingdom and Malta the limit is 0.8 ‰. In Iceland and Switzerland the limit is 0.5 ‰. The Czech Republic, Hungary, Romania and Slovakia have applied zero tolerance. In many countries a lower limit than the official one is applied to professional drivers and novice drivers [4]. A novice driver is defined as a new driver regardless of age. However, age limits are also valid in many countries. In the United States the general limit is 0.8 ‰ and the limit is at highest 0.2 ‰ if the age is below 21 years. The limit is 0.4 ‰ for professional drivers [5]. In Australia the general limit is 0.5 ‰ and for professional drivers and novice drivers there are different practices in different states. In New South Wales zero tolerance is applied for these two groups [6]. In Victoria the limit is also zero for professional drivers and for novice drivers during the first 3 years [7]. Evidential breath samples are also widely used. The corresponding limits vary depending on the applied blood:breath ratio[8].

European Union has announced a directive in 1991 (91/439/ETY) and an updated version in 2006 (2006/126/EY) in which is demanded that a driver's license should not be permitted or regranted if the person is addicted to alcohol and/or other drugs.

2.1.2 Prevalence of drunk driving and drivers who "had been drinking"

The prevalence of drunk driving depends on the population studied. Apprehended drunk drivers are usually caught during ordinary police work and thus the results depend on the activity of the police. In Finland about 23 000–24 800 drunk drivers were annually apprehended during the period 2006–2008. The most common reasons for being caught were road block, driving behavior, and denunciation and traffic accidents. Most of the drunk drivers were caught during weekends [9]. National statistics give information only on drivers who have been arrested during ordinary

police work. Local roadside surveys often differ both methodically and periodically. One can therefore not estimate a general prevalence of drunk driving based on these surveys. To receive reliable information on the rate of drunk driving in the traffic flow, the roadside surveys have to be performed systematically and designed in such a way that the results are comparable over time.

The systematic RBT method was introduced in Australia in the jurisdiction of Victoria as early as 1976. Ten years later the method had been brought into practice in all jurisdictions [10]. The method demands that police officers are allowed to ask drivers for a breath test even with no suspicion of drunk driving. The method gives without doubt the most reliable information on the prevalence of drunk driving in the traffic flow and the method covers all types of drivers during the time period. In New South Wales in Australia the RBT method was started in 1982. The impact of the method on daily fatal crashes was studied during an 11 year period together with the impact of other initiatives as increased penalties and introduction of a lower legal BAC limit (0.50 ‰). It was demonstrated that introduction of RBT reduced fatal crashes with 19.5 % overall and 30 % during holiday periods [11,12]. Also in a study in Victoria it was shown that the introduction of the RBT method reduced the fatal DUI accidents by 49 % (113 to 49) from 1989 to 1994 [13]. The success of the RBT method is based on the principles of high visibility and enough enforcement to ensure credibility. The surveys should be unpredictable both in its timing and location [10,13,14]. The RBT method is nowadays widely used in many countries in Europe, New Zealand and some states in America [15].

Systematic roadside surveys have been carried out in the province of Uusimaa in southern Finland since 1979. The roadside surveys have monitored the traffic flow to determine the prevalence of drivers with a detectable amount of alcohol in the blood. The surveys have been carried out at comparable places and times and the police has been used the same protocol throughout the years. In 1979 the prevalence of drunk drivers was 0.5 %. The prevalence of drivers, who had consumed alcohol but whose blood alcohol concentration (BAC) remained below the legal limit, i.e. who "had been drinking", was 1.16 % [16,17]. During the next five years the prevalence came down and has since then been around 0.2 % for drunk drivers.

The prevalence of drivers, who "had been drinking" was about 0.4 % in 1990's [18-20]. However, the prevalence began to increase in the early 2000's and was highest at 1.11 % in 2005 [20-22]. Thereafter it came down and remained during 2009–2012 at a level of 0.63–0.78 %. However, the prevalence was still 44 % higher in 2012 than in 1996 (95 % Confidence Interval, CI 13.1-82.4) [23]. The taxation of alcohol beverages was lowered in 2004 in Finland by about 30 %. The overall alcohol consumption increased 10 % from 2003 to 2004 and further 2 % in 2005 [24]. These facts might have influenced at least to some extent the increase in the prevalence of drivers "who had been drinking" (paper II and paper IV).

The prevalence of drunk driving has by roadside surveys in Sweden been estimated at 0.24 % and in Norway at 0.3 % [25,26]. The legal limit is 0.2 ‰ in both countries. In the Norwegian study, the prevalence of drivers who had a BAC of at

least 0.5 ‰ was 0.1 %. In the European Union (EU) the project Driving Under the Influence of Drugs, Alcohol and Medicines (DRUID) was started in 2007. Thirteen countries were involved in the project. In Finland the prevalence of drivers with a BAC of at least 0.5 ‰ was 0.20 % and of drivers who "had been drinking" 0.76 % [27]. In Sweden the prevalence of drivers with a BAC of at least 0.2 ‰ was 0.18 % [25]. In Norway the prevalence of drunk drivers was 0.3 % [28]. In Denmark, where the statutory limit is 0.5 ‰, the prevalence of drunk drivers was 0.48 % and that of drivers, who "had been drinking" 2.05 % [29,30]. The highest values were found in the south and east Europe and the lowest in north Europe. The mean prevalence in EU of drivers, who had a BAC of at least 0.5 ‰ was 1.49 % and the mean prevalence value for drivers with a BAC of at least 0.1 ‰ was 3.48 % [31,32].

In the Spanish DRUID study some type of psychoactive substance was detected in 16.96 % (560/3302) of the tested drivers. Alcohol alone was found in 6.61 % (218/3302) of the subjects. The legal limit for breath alcohol is 0.25 mg/l and of the alcohol positive subjects, the reading exceeded this limit in 31 % of the subjects (68/218). The prevalence of drunk driving was thus 2.05 % (68/3302) and that of low alcohol concentration 4.56 % (150/3302) [33].

In the United States in a study in 2007 the prevalence of drivers, who had a BAC of at least 0.5 ‰, was found to be 0.1 % during daytime and 4.5 % during night time. The prevalence of drivers, who had a BAC below 0.5 ‰, was 0.9 % during daytime and 7.9 % during night time [34]. In Canada in a study in 2008 the prevalence of drivers, who had a BAC of at least 0.5 ‰ was 4.1 %. The corresponding figure for drivers with a BAC below 0.5 ‰ was 4.0 % [35]. In Belgium random roadside surveys have been carried out since 2003. In 2005 the prevalence was 3.31 % for drivers with a BAC of at least 0.5 ‰ [36]. In 2010 the prevalence for drivers with a BAC of at least 0.5 ‰ was found to be 2.0 % [37].

2.1.3 Risk factors for drunk driving and recidivism

The most common definition of recidivism is a relapse based on statutory limits. A broader definition includes driving under influence of any amount of alcohol and/or drugs [38]. It has been shown in numerous studies that roughly one-third of drunk drivers repeat the offense [18,38-50]. The time span in the studies of recidivism has varied between 2 years and up to 30 years. Most studies are based on drunk drivers apprehended during ordinary police work.

The term "hard core" drunk driver has been developed in the 1990's by researchers in Canada and USA. A hard core drunk driver is defined as a driver, who has driven with a BAC of 1.50 ‰ or higher or a driver, with more than one DUI [51].

Recidivism was investigated in a Finnish study during a period of almost 20 years from 1971 to 1993. In total, 8183 drivers were studied. About one-third had an earlier DUI during 5 prior years and the percent increased to 40 % when the time

span was 10 years. During the ten year period the highest percentage, 55 %, was found in the age group 35–39 years old males [43].

In Norway 2400 drunk drivers were investigated for recidivism. The subjects were selected from four years during the late 1980's and early 1990's. Of the drivers 94 % was male 6 % female. The study period was 11 years. Of the drivers 45 % were found to be recidivist with respect to alcohol and/or other drugs. The percentage for females was significantly lower, 32 %, than that for male drivers, 55 %. Multiple arrests were more common in higher BAC groups [44]. In another study, partly based on the same subjects, recidivism between drugged and drunk drivers was compared. The BAC of the drunk drivers was between 1.6 ‰ and 1.9 ‰. These 850 drivers were followed prospectively 7 years. The recidivism rate was found to be 28 % for drunk drivers and 57 % for drugged drivers [49].

Five risk factors for recidivism were determined by combination of psychometric and demographic variables in a study in 2001. The factors were if the age was below 29 years, number of years of education was below 12 years, a BAC of 2.0 ‰ or higher at the time of arrest and scores of the tests Alcohol Use Disorders Identification Test (AUDIT) and MacAndrews Alcoholism Scale (MAC).The final sample consisted of 1496 drivers, who were drawn from 4993 DUI offenders between 1989 and 1991 [45].

The criminal history of 1830 drunk drivers was investigated during a five-year period in 1997–2001 in Sweden. Both traffic violations and other crime types were recorded as well as the BAC and the alcohol consumption based on the AUDIT questionnaire. The drivers were followed up during the next two years and the purpose was to find out if an earlier DUI offence predicted recidivism. It was demonstrated that 30 % of the drivers with an earlier DUI recidivated during the following 2 years and 10 % of those without a previous DUI. A prior DUI offence was found to be a significant predictor for relapse. It was also shown that 40 % of the drunk drivers had other criminal violations, which is about four times higher than in the general population. Additionally it was found that drunk drivers detected during afternoon between noon and 7 p.m. had the highest scores in the AUDIT test [52].

In a recent long-term study in Finland it was shown that one third of drunk drivers arrested during ordinary police work repeated the offence during a 15-year period [53].

In a study in USA 77 drunk drivers were investigated for recidivism prospectively the following 12 years. Of the drivers, 38 % were rearrested for DUI. It was demonstrated that an earlier conviction of drunk driving predicted later recidivism. The mean time span between the first and the second offence was 6 years. No gender difference or age difference was found. The mean BAC was 1.64 ‰ in one-time offenders and 1.80 ‰ in recidivists and no difference were found between the groups. However, a difference was found in the result of the MAC test. The recidivists had significantly higher scores than the one-time drivers. In the driving history the recidivists had significantly more remarks according to e.g. reckless driving and revoked driving license [54].

In a large study in Maryland in USA about 100 million driver records were investigated focusing on recidivism and risk factors for further drunk driving during

1973 and 2004. The study period was from 1999 to 2004 and the 21 million drivers were classified into four groups. The groups were drivers with 0,1,2,3 or 4 earlier alcohol-impaired driving events. It was demonstrated that the recidivism rate among first offenders resembled more closely that of second offenders than of those with no alcohol-impaired driving event. The annual rate of a subsequent violation was found to be 7.15 times higher among drivers with one earlier drunk driving event than drivers with no earlier drunk driving event. For drivers with two earlier drunk driving events, the rate was 10.6 times greater compared to no earlier events. For drivers with three or more earlier events the rate was found to be 14.9 times higher compared to those, who had no earlier drunk driving events [55]. In another study based on the same material, it was concluded that regardless of sanctions imposed a first-time DUI offender always has a relatively high risk of recidivism [56].

Recidivism has been investigated in Finland also among drunk drivers in road-side surveys in the 1980's and early 1990's. The rate of recidivism was found to be about 25-50 % during a period of 5-12 years [18,19,50,57]. Drivers, who "had been drinking", but whose BAC was below the legal limit, were also reported to have been convicted for drunk driving earlier. The rate varied between roughly 10-30 % and the information was based on interviews [18].

The relationship between the BAC at arrest and recidivism was investigated in a study of in total 53 217 drivers. Demographic factors and driving history were also studied with both complex and simple prediction models. A relationship was found between BAC at arrest and recidivism during one following year. First time offenders with high BAC levels have about the same recidivism rate as repeat offenders. The rate was quite high even if the BAC was 0.00 ‰, which indicates the use of other drugs than alcohol. It was also demonstrated that repeat offenders had 14.8 % greater probability of recidivating than first offenders [58].

2.2 The profile of drunk drivers and drivers who "had been drinking" in roadside surveys

A drunk driver in road-side studies in Finland was in the 1980's and early 1990's mostly a man with a mean age of 37.6 years. Only 6.9 % were women. The mean BAC±SD was 1.06 ± 0.46 ‰. A driver who "had been drinking" was also mostly a man, 8.4 % were women. The mean age was 36.6 years. It was also found that the GGT level was above the reference limit in about 40 % of drunk drivers and almost the same in drivers who "had been drinking". The highest values were found in early afternoon traffic on Tuesdays at 4–6 p.m. The proportion of professional drivers was about 10 % for drunk drivers and about 9 % for drivers who "had been drinking". About 8 % of drunk drivers did not have a valid driving license. The corresponding value for drivers who "had been drinking" was 2.4 % and the difference was found

to be highly statistically significant. In the study a comparison between sober drivers and alcohol-positive drivers was also made. It was demonstrated, that in the sober group there were higher proportion of women, of married drivers, of license holders, and more drivers who owned their car. In the sober group were lower proportion of blue collar workers and recidivists. It was found that drunk drivers and drivers who "had been drinking" resembled each other in many respects. It was thus concluded that a great number of drivers who "had been drinking" actually belong to the drunk drivers group, although the BAC at that time did not exceed the legal limit [18].

In a Finnish study drunk drivers and drivers who "had been drinking" in roadside surveys were compared between 1979 and 1998. Sober drivers were also interviewed. In 1979 the number of subjects was 186, 393 and 758 and in 1998 81, 110 and 1247, respectively. It was concluded that drunk driving is a male problem, although the number of women had increased. It was also demonstrated that the age of a drunk driver was higher in 1998 than in 1979. In 1998 there were also more drivers in a manager employment relationship and more functionaries with a higher education degree compared with the subjects in 1979. The drivers who "had been drinking" resembled more the sober drivers than the drunk drivers in that connection [59].

In a Canadian study the driver was a man in 78.4 % of the 1389 alcohol positive drivers. Regardless of the lower figure for women, they were just as likely to drive with a BAC above 0.8 ‰. In the age groups 19 to 44 years drivers were most likely to have been drinking. None of drivers between 16 and 18 years had a positive BAC. In the age group 25 to 34 years a BAC of 0.50 ‰ or higher was more usual as well as a BAC of 0.80 ‰ or higher [35].

Results from the DRUID study in Norway showed that alcohol as well as other drugs was more likely found in male drivers. Alcohol was more common in older age groups [28].

In the DRUID study in Denmark it was found that 89 % of alcohol positive drivers were men and the median age was 48 years (range 19–78 years). The alcohol concentration measured in oral fluid was converted to BAC and the corresponding range was 0.07-1.28 g/l. The mean BAC was 0.33 g/l [30].

The Spanish DRUID study demonstrated that drunk drivers were more likely found as the age increased. A substance positive (alcohol and/or illicit drug) driver was more likely a man than a woman [33].

2.3 Biomarkers, alcohol and drunk driving

2.3.1 Classification

Alcohol biomarkers are defined as follows: "Chemical or physiological indicators of exposure to alcohol or consumption to an extent that causes damage to organs and tissues. In general a biochemical test entails the analysis of an endogenous substance,

that can be used to measure the prognosis of a disease or the effect of a treatment" [60]. The biomarkers are classified depending on their characteristics and clinical application. A biomarker can be an abnormal metabolite or a change in the concentration of an enzyme, which can be related to alcohol consumption. Two kinds of biomarkers are defined, namely trait markers and state markers.

Trait biomarkers are also referred to as biomarkers for predisposition for alcoholism. They provide an important research tool in evaluating genetic and environmental factors, which may contribute to alcoholism. One example of a trait biomarker is the enzyme monoamine oxidase (MAO), which is involved in the catabolism of dopamine, norepinephrine and serotonin. One mutant form of the enzyme aldehyde-dehydrogenase (ALDH2) is another example of a trait marker. This enzyme oxidizes the second step in the metabolism of ethanol, which is the formation of acetate from acetaldehyde. Many individuals in the East Asians have inherited an inactive enzyme and they are highly sensitive to even small amounts of alcohol. The reason is elevated levels of acetaldehyde in the blood, which leads to increased skin temperature and a flush reaction [60].

Most of the conventional alcohol biomarkers are state markers. They reflect alcohol consumption and give a measure of both chronic and acute consumption. An ideal alcohol biomarker is specifically related to the use of ethanol and/or its metabolism. The biomarker is dependent on the amount alcohol consumed and be highly sensitive. An ideal biomarker is able to discriminate social drinkers from heavy drinkers and shall also react on abstinence in a definable way.

Diagnostics tests are evaluated based on their ability to discriminate correctly between individuals who have the condition of interest from those who do not. Sensitivity and specificity are two test characteristics that must be known to make this distinction. Sensitivity is the proportion of individuals with a condition who have a positive test, while specificity is the proportion of individuals without the condition who have a negative test. The terms are expressed in percentage.

Ethanol in blood, breath, saliva and/or urine determined by a sensitive and specific method proves that a person has recently drunk alcohol. In forensic laboratories, the headspace-gas-chromatograph (HS-GC) method is widely used. The matrix is mostly whole blood and the sample is taken into special tubes with a preservative to prevent alcohol formation post sampling. Ethanol in breath is often indicated by the use of an alcohol field screening device and the confirmation made by an evidential breath alcohol analyzer. These analyzers have already been used for decades worldwide. In Finland they were taken into usage in 1998 and the system is supported by a centralized quality control program [61].

More recently, products of the metabolic pathway of ethanol have also been in focus as markers of ethanol consumption. The metabolites ethyl glucuronide (EtG) and ethyl sulfate (EtS) can be demonstrated in blood and urine even after that the ethanol concentration has reached zero. These metabolites are important in the field of forensic toxicology because they show that ethanol has been recently consumed [62].

Phosphatidylethanol (PEth) is an abnormal phospholipid, which is formed by an enzyme, phospholipase D, in the presence of ethanol. The affinity for ethanol is over 1000-fold higher than for water and thus PEth is formed instead of the normal products, phosphatidic acid and choline. PEth can be demonstrated in blood even up to 2 weeks after that the ethanol consumption has been finished. The specificity as a marker is 100 % because PEth can be formed only by the presence of ethanol [60].

The ratio in urine of the serotonin metabolites 5-hydroxytryptophol (5-HTOL) and 5-hydroxyindole acetic acid (5-HIAA) increases after ethanol consumption and can thus be used as a marker. The ratio remains elevated for 2-10 hours after that the ethanol concentration is zero [60].

The aminotransferases, aspartat aminotransferase (ASAT) and alanine aminotransferase (ALAT) has only limited values as biomarkers of ethanol consumption. The enzymes are elevated in almost all liver diseases and thus the specificity for ethanol consumption is classified as low. The sensitivity is between 15–69 % for ASAT and 26–58 % for ALAT. The half-time for alcohol elevated levels is about 2–3 weeks [60].

The mean corpuscular volume (MCV) is an index of red blood cell size. MCV is elevated in alcoholism, but also of other reasons, i.e. drug use. After a drinking period of about 4 to 8 weeks the level of MCV is increased. As a biomarker of ethanol consumption, MCV should be used as a compliment together with more specific biomarkers [60].

2.3.2 γ–Glutamyltransferase (GGT)

One of the first used transaminases for detection of excessive alcohol use is the enzyme γ–glutamyltransferase, GGT. Both in clinical applications as well as in traffic medicine, GGT is still considered a reliable and useful analysis. Serum GGT is one of the most widely used laboratory screening test as a biomarker of excessive alcohol use. The analysis is quite easy to perform and the costs are at a reasonable level. Serum GGT values depend on both age and sex. Normal values are greater in men than in women and the values increase in adults with the age.

The systematic name of GGT is (5-Glutamyl) -peptide:amino-acid 5-glutamyltransferase and the numerical designation EC number is 2.3.2.2 (EC=Enzyme Commission). GGT belongs to the second of six enzyme classes, the transferases. The classification depends on the type of enzymatic reaction. GGT is a liver enzyme present mainly in the cytoplasm. GGT catalyzes the transfer of a glutamyl group from a glutamyl-peptide and an amino acid to a peptide and a glutamyl-amino acid (Figure 1).

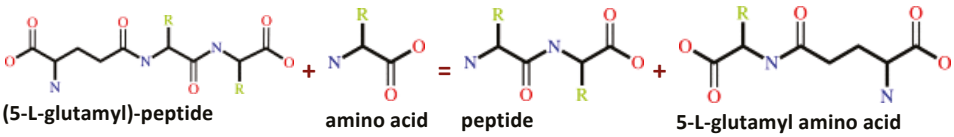

Figure 1. Schematic description of the reaction catalyzed by GGT. (Molecule diagrams generated from .mol files obtained from the KEGG ftp site.)

GGT is also present in proximal renal tubule, pancreas and intestine. In serum GGT is primarily originated from the hepatobiliary system. The specificity of GGT is not very high, a fact which limits its utility. The sensitivity has been estimated to 34–85 % and the specificity to 11–85 %. Elevated values are found in the majority of serum from heavy drinkers, but are also found after use of drugs as barbiturates and phenytoins [63]. Despite its poor specificity, 50–72 % of elevated GGT levels can be explained by excessive alcohol consumption. The power of GGT can be increased when it is used together with other biomarkers [60,64].

Chronic alcohol intake increases the level of GGT perhaps by accelerating the GGTs synthesis by liver cells and/or prompting its release from dead or membrane-damaged liver cells. After a drinking period of > 60 g/day for several weeks increased GGT values are measured. The half-life of GGT is estimated between 14–26 days [65].

2.3.3 Carbohydrate deficient transferrin (CDT)

Transferrin (Tf) is a glycoprotein, which is synthesized in the liver. In the 1970's the Swedish researchers Stibler and Kjellin detected a different form of transferrin (Tf) in cerebrospinal fluid and serum samples from alcohol abusers. This abnormal Tf disappeared during abstinence, but was again detectable after some time of alcohol use. The marker consists mainly of minor isoforms of Tf which are deficient in the terminal trisaccharides. The isoforms are mainly asialo-, monosialo- and disialotransferrin. The decrease in number of carbohydrate chains refers to the acronym carbohydrate-deficient transferrin (CDT) [66].

Human Tf is the principal plasma protein for the transport of iron (Fe^{3+}). The molecule consists of two globular domains (C-terminal and N-terminal) of a single polypeptide chain with a molecular weight of approximately 78 k Daltons. Tf is composed of 679 amino acids. The N-terminal domain consists of the amino acids 1-336 and the C-terminal domain of the amino acids 337-679. Each domain has a

single iron-binding site. The sites usually bind two bi- and/or triantennary carbohydrate chains. These chains are of variable composition and contain four different carbohydrates. They are N-acetyl-glucoseamine, mannose, galactose and sialic acid (N-acetyl-neuraminic acid) terminals. Since the only charged carbohydrate is sialic acid, reduced contents of this molecule result in increasing amounts of components with higher isoelectric points (pI). The normal main (80–90 %) isoform of Tf has a pI of 5.4 with four sialic acid rests, two on each chain (tetrasialo-transferrin). Minor isoforms have two, three, five and six residues. Traces of asialotransferrin and monosialotransferrin can be determined. The isoforms can be separated by electrophoresis. On the bases of scientific consensus, the glycoforms collectively referred to as CDT include asialo-, monosialo- and disialo-Tf [67-70]. The structure of CDT is shown in Figure 2 and that of sialic acid in Figure 3 [71].

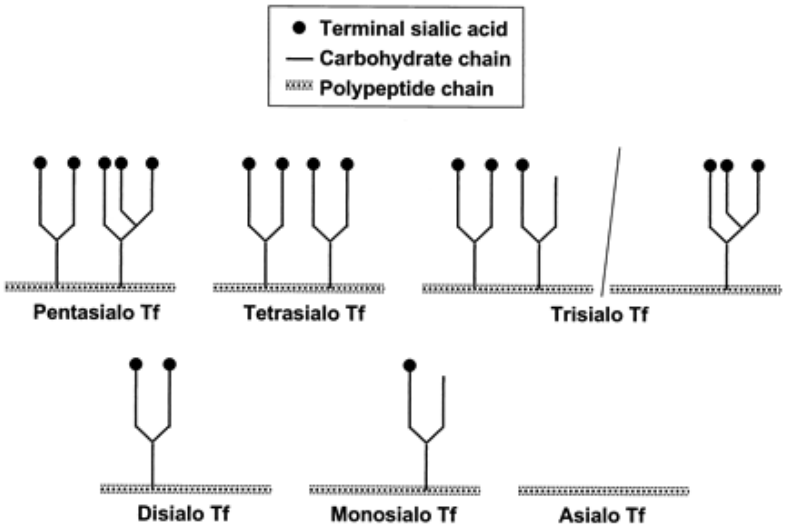

Figure 2. Schematic structure of the different isoforms of transferrin and the glycoforms referred to as CDT (asialo-, monosialo- and disialo-Tf).

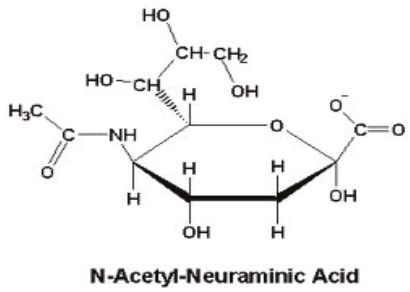

Figure 3. Structure of sialic acid (N-acetyl-neuraminic acid).

The synthesis of Tf occurs in hepatocytes in the liver and involves the final addition of sialic acid residues to the terminal end of the glycoprotein. The mechanism behind the final formation of CDT is still not fully understood. It is also unclear if it is ethanol itself and/or its metabolite acetaldehyde which affects the addition of sialic acid. The glycosyltransferases, which are located in the Golgi apparatus in the hepatocytes, are involved in the synthesis of the side chains in the Tf molecule. It has been shown in rats that ethanol decreased the hepatic synthetic rate of sialyltransferase, which leads to impaired sialylation of Tf [72]. Increased sialidase activity in liver plasmamembranes and reduced glycosyltransferases in Golgi homogenates has been found in rats fed with alcohol. Acetaldehyde was also found to reduce the activity of glycosyltransferases [73].

Based on a large number of publications there is an agreement that a daily intake of about 60–80 g alcohol over 1–2 weeks increases the level of CDT. The mean half-life is about two weeks [66,68,74,75].

2.3.4 Combination of CDT and GGT

Sillanaukee et al., (2000a) and Sillanaukee and Olsson (2001) were the first who applied a mathematical combination of GGT and CDT. The aim was to find which combination among traditional biomarkers that best discriminated between high alcohol consumption and controls. The biomarkers were CDT, GGT, ASAT, ALAT and MCV. A combined marker of GGT and CDT (γ–CDT = 0.8 x ln GGT + 1.3 x ln CDT) clearly outperformed both CDT and GGT. The other markers added explained only a small part of the variation. The statistical method used was discriminate analysis. The number of subjects in the first study was 4011 women and 4014 men. The number of subjects in the second study was 472 alcohol abusers (> 60 g absolute alcohol/day) and 940 controls (< 60 g/day) in six different studies in Europe. The cut–off for γ–CDT was determined to 6.5 for both females and males. For males the average sensitivity and specificity of the combination γ–CDT were 75 % and 93 %, respectively. The corresponding values for CDT were 58 % and 94 % and for GGT 55 % and 90 %. An improvement was thus significant. The combined biomarker was recommended in clinical settings because it is both easy to apply and cost-effective [64,76].

In another study of Sillanaukee et al., (2000b), γ–CDT was applied to discriminate between heavy drinkers (> 280 g/week), moderate drinkers (105–280 g/week) and light drinkers (<105 g/week). The number of subjects was 6962 in total from five different geographic areas in Finland. The combined biomarker had the highest specificity and sensitivity in all groups and showed that the biomarker was a good indicator also in general population [77].

It has been shown also in other studies that the mathematical combination of CDT and GGT gave an improvement of diagnostic performance. In a study by Chen

et. al., the combination enhanced the detection of problem drinking in men. The daily alcohol amount was 60 g or more during 30 days. In women GGT alone gave the best result. In the study 1863 subjects participated from five countries [78]. In Germany the combination of CDT and GGT was included in a model together with the result of the AUDIT questionnaire and a judgment by a physician. This model showed higher specificity and sensitivity than the markers alone. A total of 2940 patients participated in the studies [79,80].

In the studies performed by Sillanaukee et al., (2000a, 2000b, 2001) the method used for determination of CDT was the immunological CDTect method. However, the same mathematical combination was also applied by Anttila et. al.,(2003) in a Finnish study in clinical settings where the CDT determination was made also by the more specific Axis %CDT assay. This assay has a better analytical performance. The assay measures the Tf isoforms asialo-, monosialo- and disialo-Tf and and this γ −%CDT value is expressed as a percentage of total Tf. The cut−off for γ−%CDT was determined to 4.0. The study population was alcoholics, 34 with liver disease and 31 without liver disease. In the reference group was 45 individuals. In all groups the combined biomarker γ−CDT (CDTect method) classified correctly alcohol abusers. The biomarker γ −%CDT showed a sensitivity of 92 % and a specificity of 100 %. It was concluded that the method has significant clinical value in evaluating the level of alcohol use among individuals [81]. In another Finnish study it was shown, that the combination of CDT and GGT classified correctly heavy drinkers. The sensitivity was 90 % and it was clearly higher than that of each marker alone. In the study 165 heavy drinkers participated [82].

2.3.5 Biomarkers and drunk driving

Alcohol biomarkers have been used in numerous studies of drunk driving to estimate the degree of alcohol consumption of the driver. In Finland GGT, ASAT and ALAT have been used in the 1980's and early 1990's. It has been shown that at least one third of drunk drivers had elevated levels of these biomarkers and it was concluded that a considerable proportion of problem drinkers exists among drunk drivers [18,50,57]. Measurements of both GGT and CDT have been used in many studies of drunk drivers in the 1980's and 1990's [83-91].

In Sweden alcohol abuse or dependency is a reason for denial of the driver license. Biochemical markers are involved in the intervention and both CDT and GGT are used. However, a mathematical combination of these two markers is not applied. Also ASAT, ALAT and MCV are measured [92].

In a study in Germany four markers were combined to form an index called the Alc-Index. This index consisted of determination of methanol, acetone, 2-propanol, GGT and CDT. The mathematical index was developed by logistic regression. In the study 341 subjects participated. The subjects were divided into three groups

depending on the level of alcohol consumption. It was found that none of the non-alcoholics exceeded the cut-off, while about 93 % of the alcoholics did exceed the cut-off [93]. In another study the individual Alc-Index was calculated in 327 alcohol-impaired drivers. It was shown that 48 % of the subjects could be classified as alcohol dependent [94].

In Wisconsin in the USA, CDT was used together with a test, the Early Detection of Alcohol Detection (EDAC) test, which is a statistical model of predictions using 20 routine laboratory tests. In these laboratory determinations among others also GGT, ASAT, electrolytes and HDL cholesterol are included. The subjects were 200 drivers who had been convicted for drunk driving three or four times earlier. They were therefore considered as most likely to be alcohol dependent. The BAC should also be 1.5 ‰ or higher. The drivers were followed up during one year and the tests were performed four times during the period. A combination of EDAC and CDT gave the best result. About 20 % of the drivers were considered heavy drinkers and 52 % reduced or abstained their drinking during the period. It was concluded that the EDAC and CDT combination was an objective, useful and cost-effective tool to identify alcohol problems and to reduce drunk driving [95].

In Canada in a large study the driver risk was estimated by using biomarkers, blood alcohol concentration calculated from measures by interlocks and psychometric assessment. The biomarkers were among others CDT and GGT. However, no mathematical combination of these two markers was supplied. Direct markers, which are metabolites of ethanol, as PEth, EtG and EtS were also used. In the study 346 first offenders and 183 multiple offenders participated. Recidivism was investigated in the prior ten years. Fifty-one percent of the subjects met DSM-IV criteria for alcohol dependence or abuse. Failed interlock tests were expressed as a rate relative to all tests taken. The subjects used the car 277 days and a mean of 2800 tests were performed. Of all tests 63 % were start-up tests. It was found that higher biomarker levels predicted higher rates of test failures [96].

In another study in Canada the utility of biomarkers in drunk driving were tested. The biomarkers were ASAT, ALAT, GGT, MCV, CDT and thiamine. Both first-time offenders (n=49) and recidivists (n=95) participated. It was found that biomarkers alone or in combination did not indicate that recidivists were more often problem drinkers than first-time offenders. The combination of CDT and GGT was calculated according to Sillanaukee and Olsson. There was no significant difference in the combined γ-CDT between first-time offenders and recidivists. As cut-off 6.5 was used [97].

In Italian drivers it was shown that a relevant proportion of those with a high BAC are chronic alcohol abusers. In total 966 men and 394 women participated in this study. In the control group were 336 men (alcohol consumption < 210 g/week) and 316 women (< 140 g/week). In the second group were 552 men and 51 women who all applied for driving license after a rehabilitation period. In the third group 78 men and 27 women had been involved in traffic accidents and their BAC had at the time of the accident been at least 0.5 ‰. CDT was measured by a commercial kit

based on High Performance Liquid Chromatography (HPLC) following international recent recommendations (IFCC-WG-CDT =Working group on standardization of carbohydrate-deficient transferrin; International federation of Clinical Chemistry and Laboratory Medicine) and was reported as a percentage of disialotransferrin to total transferrin. CDT and GGT were combined according to Sillanaukee and Olsson and modified by Anttila et al., as described earlier in 3.4.4. It was found that the combination was less sensitive than CDT measured alone. Thus it was concluded that the combination of GGT and CDT should not be used in traffic medicine in the same way as in clinical settings [98].

2.4 CAGE questionnaire

The CAGE questionnaire as a screening instrument for harmful use of alcohol and alcohol dependence was originally developed in the early 1970's and 1980's [99,100]. It consists of four questions and has been widely studied because of its ease of administration. The four questions are: 1. Have you ever felt you ought to Cut down on your drinking? 2. Have people Annoyed you by criticizing your drinking? 3. Have you ever felt bad or Guilty about your drinking? 4. Have you ever taken a drink first thing in the morning to steady your nerves or get rid of a hangover (Eye-opener)? Each affirmative response gives one score. A cut-off of two or more has been used to indicate a positive test.

In a study during a six-month period consisting of 521 hospital patients, the sensitivity and specificity of the CAGE for alcohol abuse or alcoholism were 85 % and 89 %, respectively. The positive predicted values of the CAGE varied between 62 % for one affirmative response to 100 % for 4 affirmative responses [101].

In another study one positive response had a sensitivity of about 90 % and four positive responses had a nearly 100 % specificity of harmful use of alcohol or alcohol dependence [102].

For harmful alcohol use and alcohol dependence the sensitivity was 54 % and 49 %, respectively and the specificity 89% and 98 %, respectively, in a study by Wetterling et al. In this study CAGE was also found to correlate with CDT in males [103].

In a study among Finnish males a cut-off of three scores indicated heavy alcohol consumption. The subjects were 318 men in a health care clinic. Of male heavy drinkers, 15 % were detected both by CAGE and by self-reported alcohol consumption, 77 % only by CAGE and 79 % only by self-reported consumption. In the primary health center there were significantly more patients having four scores of the CAGE than in general population [104].

On the basis of a review consisting of 35 articles using the Diagnostic and Statistical manual of Mental disorders (DSM) as a golden standard, it was concluded that the CAGE as a screening instrument is only of limited value at a cut-off of two positive scores. It was recommended that additional information should be obtained from all patients who have one positive answer on the CAGE [105].

3 Aims of the present study

- to determine and follow up the prevalence of alcohol positive drivers in the traffic flow
- to determine the profile of an alcohol positive driver
- to evaluate the combination of CDT and GGT in two different groups of drunk drivers
- to determine risk factors for drunk driving based on comparison with sober drivers
- to determine risk factors for recidivism

4 Subjects and methods

4.1 Study design and subjects

4.1.1 Subjects in the long-term study

The roadside surveys were carried out during spring and autumn on Tuesdays and Saturdays. The sessions were held during early morning and late evening. On Tuesdays a late afternoon session also occurred. The weekdays and the times were chosen to represent both average weekday and weekend traffic. The surveys were carried out in the greater Helsinki area, which included, besides Helsinki, Espoo and Vantaa. Surveys took also place in Lohja, Vihti, Kerava, Nurmijärvi and Tuusula municipalities.

The team consists of a chief inspector, 8-14 police officers, one physician or nurse and a few assistants. Every session lasts about 30–40 minutes and consists of 4–5 road-blocks. During the session every driver is breath-tested. If the reading of the screening device is above 0.50 ‰, the chief inspector is authorized by law to suspend the driver's license and to instruct the physician or the nurse to take a blood sample for determination of the blood alcohol concentration. If the result was ≥ 0.50 ‰, the driver was recorded as a drunk driver. However, the final classification of a driver as a drunk driver was confirmed by the result of the blood sample.

If the reading of the screening device shows that the driver has been drinking, but the reading remains below 0.50 ‰, the driver is recorded as one who "has been drinking". The method of the surveys is described in detail earlier (paper I) [18].

All alcohol positive drivers were on voluntary basis interviewed for demographic characteristics and driving habits. The questionnaire included gender, age, marital status, profession, employment status, class of driving license, estimate of annual driving kilometers, the specific driving event (starting point and goal) and the aim of the specific drive. The drivers were also asked about their opinion of the risk at a general level for a drunk driver being caught. The number of passengers was recorded.

Annually a total of about 20 000–30 000 drivers were breath-tested in the roadside surveys in Uusimaa in southern Finland. During the study period 1990–2008, 542 495 drivers were tested in total. The number of drunk drivers was 1241, of whom 1133 were men and 108 women. The number of professional drivers was 107, who were all men. The number of drivers who "had been drinking" was 3087 drivers. Of those 2699 were men and 376 women (the information of the gender was not recorded in 12 subjects and the result of the screening device in 18 subjects). Professional drivers were 234 of whom 4 were women.

During the surveys in 1998–2000 3407 sober drivers were interviewed as a comparison material. In these subjects the result of the screening device was negative.

4.1.2 Subjects in the study of biomarkers and recidivism

In 1996 and 1997 237 alcohol positive drivers in the road-side surveys gave on voluntary basis a serum sample for determination of GGT and CDT. DUI recidivism was investigated in 132 subjects whose BAC was found to be ≥ 0.50 ‰.

To compare drunk drivers in the road-side surveys to drunk drivers apprehended during ordinary police work, a pilot of 193 drunk drivers were investigated. In the greater Helsinki area drivers suspected of drunk driving are brought to a forensic medical station at the University of Helsinki. CDT and GGT were determined from serum samples. Recidivism was investigated in those subjects whose BAC exceeded the limit 0.50 ‰ (n=173).

In addition the drivers were interviewed about their alcohol consumption using the structured questionnaire CAGE.

These subjects are described in detail earlier (paper I). The study was approved by the Ethics Committee of the Institute for Health and Welfare (former National Public Health Institute).

4.2 Methods

4.2.1 The screening device

For the alcohol field-screening tests the devices Alcometer PST–M1R and Alcometer PST-SM2 (Lion laboratories Ltd., Cardiff, U.K.) and the Alcosensor III R (Intoximeters Inc., Saint Louis, Missouri, U.S.)were used. The alcohol field-screening devices were programmed to display the value of the blood alcohol concentration based on a 2100:1 blood to breath ratio. The reading 0.01 ‰ was regarded positive if it was a result measured by at least two devices. The device that confirmed the first result was always kept in a police car, which guaranteed that this second measurement was performed under stable conditions.

The reading of the screening device is not evidential. Therefore if the reading was above 0.50 ‰, a blood sample from the driver in question was taken by an authorized physician, who was a member of the team. The BAC was always confirmed by using a headspace-gas-chromatograph (HS-GC) method. If the reading was below 0.50 ‰, the driver was recorded as a driver who "had been drinking" and no blood sample was taken. However, in 142 subjects the reading was above 0.50 ‰, but the result of the HS-GC method was below 0.50 ‰. These subjects were therefore recorded as drivers "who had been drinking" and not as drunk drivers.

4.2.2 Chemical analyses

The HS-GC method for determination of BAC has been described in details earlier (paper I). Serum GGT was determined by established chemical methods and 80 U/l was applied as cut-off value. Serum CDT was determined by using a commercially available kit (CDTect, Pharmacia & Upjohn Diagnostics, USA) and 20 U/l was used as cut-off value. For the mathematical combination γ-CDT a cut-off value of 6.5 was used according to Sillanaukee et al., and Sillanaukee and Olsson [64,76]. However, the CDTect kit is nowadays replaced by a more specific method Axis %CDT assay. A similar mathematical application is valid also by using this assay. As cut-off 4.0 is recommended [81].

4.2.3 Interview study

All alcohol positive drivers were on voluntary basis interviewed for demographic characteristics and driving habits. The questionnaire included gender, age, marital status, profession, employment status, class of driving license, estimate of annual driving kilometers, the specific driving event (starting point and goal) and the aim of the specific drive. The drivers were also asked about their opinion of the risk at a general level for a drunk driver being caught. The number of passengers was also recorded.

4.2.4 CAGE questionnaire

The questionnaire was carried out either by an assistant in the field or by the physician at the forensic medical station. Each affirmative response scores one point and a cut-off of two points or more indicated a positive test.

4.2.5 DUI recidivism of drunk driving

A data-base with information on the epidemiological and analytical data relating to each drunken driving event in Finland was constructed in the end of the 1980's and started to use from the beginning of 1990. The information in the data-base makes it possible to investigate the DUI events of drunk drivers both retrospectively and prospectively. In 1994 the legislation in Finland made it possible to measure the alcohol concentration also in breath with an evidential device and in 1998 evidential breath alcohol analyzers were finally implemented throughout the country. A comprehensive quality control program was constructed in connection to these devices and the analyzed breath alcohol samples [61]. Thus information of the drunk drivers, whose alcohol concentration had been measured in breath, was also archived in the same data-base.

Recidivism was investigated both retrospectively from 1990 to 1996/1997 and prospectively from 1996/1997 to 2006 in the two groups of drunk drivers described in section 4.1.2. The study was approved by the Ethics Committee of the Institute for Health and Welfare (former National Public Health Institute).

4.2.6 Statistical methods

The relationship between the blood alcohol concentration (BAC) and GGT and CDT levels were modeled using linear and logistic regression. BAC was used as a response variable and GGT and CDT were used as explanatory variables. BAC was also modeled as continuous response variable with a linear model using the biomarkers as explanatory variables. Significance was tested with the F-test and $\chi 2$–test.

Hazard of repeated drunk driving was analyzed using Cox's proportional hazards model. The explanatory variables were observed at start of follow-up and previous drunk driving in the period before start of follow-up was also used as an explanatory variable.

The risk for DUI recidivism was analyzed using the hazards model and Kaplan-Meier survival analysis. In the linear regression analyses BAC was used as response variable and GGT and CDT as explanatory variables.

The BAC was modeled by linear regression. Dichotomic response variables such as Driving Under Influence (DUI) were modeled using Poisson regression model to get better estimates for common outcomes. When sober drivers, drunk drivers and drivers who "had been drinking" were compared, logistic regression was used and the state (sober/drunk/"had been drinking") was the dichotomous outcome. Results of the logistic regression and Poisson regression analyses are presented as odds ratios (OR) with 95% confidence intervals (CI).

If the p value was below 0.05, the finding was considered statistically significant. The statistical methods are described in detail in the respective publications.

5 Results and discussion

5.1 The alcohol field screening test device

During the study period 1990–2008 the correlation between reading of the screening device and the blood alcohol concentration was 0.921 ($p<0.001$) in the drunk driver population. The mean of the reading of screening device was 0.984 ‰ (SD±0.422; n=1238, reading not recorded in three subjects).

In the driver population below 0.50 ‰ the mean of the reading of the screening device was 0.232 ‰ (SD±0.142; n=3069, reading not recorded in 18 subjects). In 342 subjects also a blood sample for BAC determination was received. The correlation between the reading of the screening device and the BAC was 0.865 ($p<0.0001$).

5.2 Prevalence of alcohol positive drivers

5.2.1 All alcohol positive drivers

The prevalence of drunk drivers and drivers who "had been drinking" is illustrated in Figure 4. The surveys were dropped from six to four Tuesdays and four Saturdays in 2006 due to reduction in the police resources. In 2006 surveys were carried out only during spring.

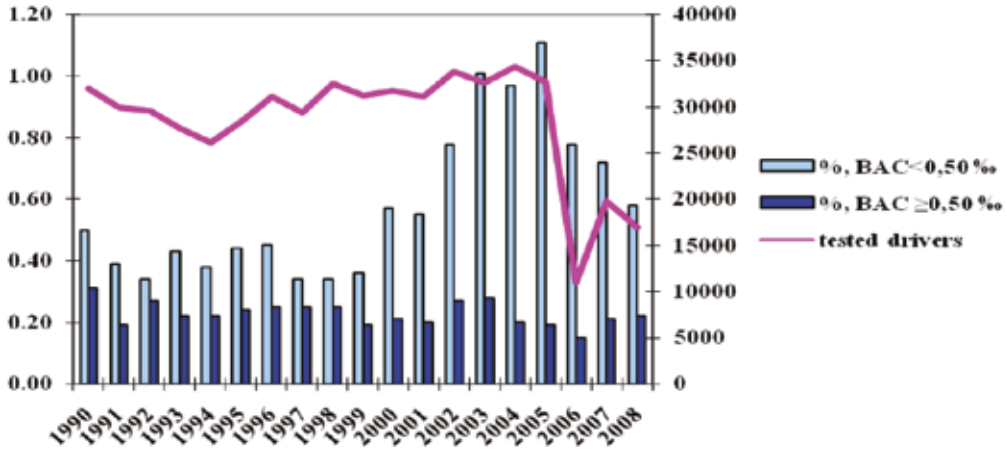

Figure 4. Prevalence (%) of alcohol-positive drivers in roadside surveys in Uusimaa 1990–2008. During 2006 surveys were carried out only in spring.

The overall prevalence of both drunk driving and drivers who "had been drinking" was at the same level in spring and autumn. However, the prevalence of drunk driving was at highest during the Saturday morning session and at lowest during the Tuesday afternoon session. The prevalence of drivers who "had been drinking" was at highest during the Saturday night session and at lowest during the Tuesday afternoon session. Details are presented in Table 1.

Table 1. Overall prevalence of drunk drivers (n=1241) and drivers who "had been drinking" (n=3087) in 1990–2008

Time of the year	≥0.50 ‰ n	Prevalence %	< 0.50‰ n	Prevalence, %	Drivers tested[1]
Spring	602	0.22	1516	0.56	271603
Autumn	639	0.24	1571	0.58	270892
Totally	1241		3087		542 495
Time of the week					
Tue 7–11 a.m.	234	0.17	386	0.28	137209
Tue 4–6 p.m.	98	0.10	242	0.25	95400
Tue 9 p.m.–1 a.m.	137	0.20	530	0.77	69044
Sat 8 a.m.–1 p.m.	571	0.35	1242	0.77	161627
Sat 9 p.m.–1 a.m.	201	0.25	687	0.87	79215
Totally	1241		3087		542 495

[1] The number includes all breath–tested drivers during the time period

5.2.2 Drunk drivers (BAC ≥ 0.50 ‰)

In the period 1990–2008 the prevalence of drunk driving did not change significantly. It was lowest at 0.19 % in 1991, 1995 and 2005. In 2003 it was at highest 0.28 %. The variation was only random and no increasing or decreasing trend was found. The legal limit for aggravated drunk driving was lowered in 1994 from 1.5 to 1.2 ‰. The taxation of alcohol beverages was lowered in 2004 by about 30 %. The overall alcohol consumption increased 10 % from 2003 to 2004 and further 2 % in 2005 [24]. No evidence of an impact from these events on the prevalence of drunk driving was found. The prevalence has remained at the same 0.2 % level also in the period 2009–2012. This means that still one in every 500 drivers is a drunk driver.

It is difficult to reliably compare the prevalence of drunk driving between countries due to different legal limits, study designs and matrixes for determination of the alcohol concentration. The prevalence of drunk driving has by roadside surveys in

Sweden been estimated to 0.24 % and in Norway to 0.3 % [25,26]. The legal limit is 0.2 ‰ in both countries. In the Norwegian study, the prevalence of drivers who had a BAC of at least 0.5 ‰ was 0.1 %. Thus, it seems that the prevalence in Finland is somewhat higher than in Norway and Sweden [25,28]. It is, however, lower than in Denmark, where the prevalence in the DRUID study for drunk driving (legal limit 0.50 ‰) was 0.48 % [29]. The mean prevalence from 13 countries in the DRUID project was expressed as a European mean percentage, 1.48 % of drivers in roadside surveys who had an alcohol concentration ≥ 0.5 g/L. The prevalence varied greatly between the countries. It was lowest in Norway, 0.07% and highest in Italy, 5.23% [31]. The 0.2 % prevalence in Finland is thus clearly below the EU mean.

In the United States the prevalence of drivers, who had a BAC of at least 0.5 ‰, was found to be 0.1 % during daytime and 4.5 % during night time [34]. The daytime prevalence in Finland (0.17 % and 0.10 % in Tuesdays and 0.35 % in Saturdays) is at the same level or somewhat higher. However, the night-time prevalence is clearly lower in Finland (0.20 % during Tuesdays and 0.25 % during Saturdays).

In Canada the prevalence of drivers, who had a BAC of at least 0.5 ‰ was in a study found to be 4.1 % [35]. In Belgium in random roadside surveys the prevalence was 3.31 % for drivers with a BAC of at least 0.5 ‰ [36]. In another study in 2010 the prevalence was found to be 2.0 % [37]. These figures are considerably higher than the prevalence in Finland (0.2 %).

5.2.3 Drivers who "had been drinking" (BAC < 0.50 ‰)

The prevalence of drivers who had consumed alcohol, but whose BAC remained below the legal limit 0.50 ‰, i.e. who "had been drinking", began to increase in the beginning of the 2000's. In the early 1990's the prevalence was about 0.4 %. The prevalence peaked at 1.11 % in 2005. After that it has varied between 0.6 % and 0.8 % even during 2009–2012, still being 1.5 times higher compared to 1996. As mentioned above, the taxation of alcohol beverages was lowered in 2004 by about 30 % and the overall alcohol consumption increased 10 % from 2003 to 2004 and further 2 % in 2005. Thus, the increased prevalence of surveyed drivers who 'had been drinking' could at least partly be explained by the increased alcohol consumption (paper II and paper IV). In the next section (5.2.4) is further investigated who caused the increased prevalence.

As with drunk drivers it is again difficult to compare the results of our study to those in other countries. In studies in many countries drivers who "has been drinking", are not even recorded. However, in results from the DRUID study it was showed that in Denmark, where the statutory limit is the same as in Finland, 0.5 ‰, the prevalence of drivers, who "had been drinking" was 2.05 % [29,30]. In the Spanish DRUID study the prevalence of drivers who "had been drinking" was 4.56 % [33]. These figures are clearly higher than in the present study (0.6–0.8 %) as well as in the results from the Finnish DRUID study (0.76 %). In the DRUID study the mean prevalence value for drivers with a BAC of at least 0.1 ‰ was 3.48 % [31,32].

In the United States in a study in 2007 the prevalence of drivers, who had a BAC below 0.5 ‰, was 0.9 % during daytime and 7.9 % during night time [34]. In Canada the corresponding figure for drivers with a BAC below 0.5 ‰ was 4.0 % [35].

It seems obvious that the prevalence of drivers who "had been drinking" is at a lower level in Finland compared to the level in many other countries. However, it should be kept in mind that there is considerably variation both in study designs and the methods used.

5.2.4 Who caused the increased prevalence in the beginning of the 2000's?

In order to find out the reason for the increased prevalence in the beginning of the 2000's these drivers were divided in two groups according to the reading of the screening device (3069/3087, information missing in 18 subjects). The two groups were drivers below 0.20 ‰ (n= 1333) and between 0.20 –0.49 ‰ (n=1736). The relative proportion of the two groups and the drunk drivers in relation to all drivers tested was modeled by multinome regression analysis. The explanatory factor was the year. The result is shown in Figure 5 and it demonstrates that the increase of drivers who "had been drinking" was caused especially by drivers below 0.20 ‰.

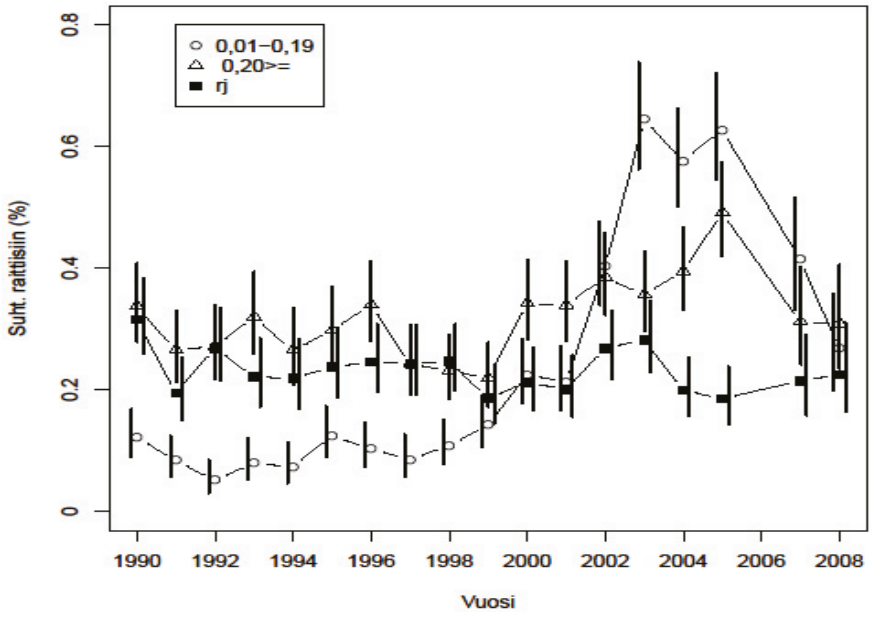

Figure 5. The relative proportion of the two groups of drivers who "had been drinking" and drunk drivers in relation to all drivers tested in 1990–2008 (suht.raittiisiin= relative to sober drivers, rj=rattijuopot, drunk drivers, vuosi=year).

It was found that the time for the survey was one reason for the increase. It was also demonstrated that drivers belonging to the group below 0.20 ‰ were drivers belonging to the age groups '≥ 55 years'. The proportion of women was also higher in drivers below 0.20 ‰. The results are presented in detail in Table 2.

Table 2. Comparison of drivers who "had been drinking" between different time periods. Odds ratios with 95 % confidential limits based on multinom logistic regression model. As reference is the period 2000–2005

Variable	1990–1999		2006–2008	
	OR	95 % CI	OR	95 % CI
BAC<0.50 ‰				
0.01–0.19 ‰	reference			
0.20 –0.49 ‰	3.3	2.73–3.92	1.06	0.82–1.37
Time of survey				
Tue 7–11 a.m.	reference			
Tue 4–6 p.m.	1.12	0.75–1.65	1.25	0.69–2.27
Tue 9 p.m.–1 a.m.	0.74	0.53–1.03	1.33	0.80–2.21
Sat 8 a.m.–1 p.m.	1.18	0.90–1.56	1.41	0.91–2.18
Sat 9 p.m.–1 a.m.	0.85	0.61–1.17	1.14	0.69–1.89
Gender				
Male	reference			
Female	0.76	0.58–0.99	1.08	0.73–1.59
Marital status				
Married	reference			
Unmarried	0.67	0.52–0.86	1.40	0.96–2.03
Cohabiting	0.59	0.46–0.77	1.04	0.71–1.55
Divorced	0.73	0.54–0.97	0.91	0.58–1.41
Widowed	5.59	1.97–15.85	2.34	0.57–9.69
Age class, year				
< 20	reference			
20–24	1.38	0.76–2.51	2.18	0.73–6.57
25–29	1.10	0.60–2.01	1.50	0.49–4.61
30–34	1.06	0.58–1.96	1.66	0.54–5.17
35–39	0.92	0.50–1.71	1.86	0.60–5.78
40–44	0.72	0.39–1.35	2.51	0.82–7.70
45–49	0.66	0.35–1.25	1.85	0.59–5.80
50–54	0.70	0.37–1.34	2.79	0.88–8.85
55–59	0.26	0.13–0.53	3.13	0.98–10.03
60–64	0.30	0.14–0.66	3.14	0.92-10.72
65–	0.24	0.10–0.61	2.87	0.76–10.82

Ownership of the vehicle				
Own	reference			
Not own	1.21	1.01–1.44	0.87	0.66–1.14
Vehicle				
Car	reference			
Other	0.71	0.24–2.05	1.34	0.28–6.39
Class of driving license				
A,B BE	reference			
C,CE,D and DE	1.02	0.85–1.23	1.02	0.78–1.33
Professional driving				
no	reference			
yes	0.78	0.47–1.28	0.68	0.28–1.65

5.3 Profile and driving habits of alcohol positive drivers

5.3.1 Drunk drivers (BAC ≥ 0.50 ‰)

Out of all 1241 subjects, the driver was a man in 91.3 % (1133/1241). The percentage of women varied randomly between 3.3 % and 16.5 %, but no increasing or decreasing trend was found. Of the 1241 drunk drivers, 108 was a woman.

The highest numbers of male drunk drivers was in the age groups 40 to 44 and 45 to 49 years. In total 31.5 % (357/1132) belonged to these groups. The overall mean age for men was 41.2 (SD±11.5) years. The age distribution is showed in Table 3.

Table 3. Distribution of male drunk drivers according to the age class

Age class	n	proportion,%
< 20	17	1.5
20–24	84	7.4
25–29	90	8.0
30–34	148	13.1
35–39	158	14.0
40–44	186	16.4
45–49	171	15.1
50–54	136	12.0
55–59	73	6.4
60–64	43	3.8
65–	26	2.3
Totally	1132[1]	100

[1]Information missing in 1 subject

The association between the age of male drunk drivers and the yearly study period was investigated by linear regression analysis, where the age was the categorical variable and the year was the explanatory variable. It was demonstrated that regardless the age of the drunk drivers varied between the years, no increasing or decreasing trend was found. In 1990 the mean age was lowest at 37.9 years and highest in 2001 at 44.7 years.

Most of the female drunk drivers were quite evenly distributed in the age classes 30 to 54 years (74.1 %, 80/108). Professional driver's most common age classes were also 30 to 54 years (76.6 %, 82/107).

Of male drunk drivers, 92.7 % (1050/1133) gave information on marital status. Forty five percent were married and 12.8 % cohabiting. There was no difference in the mean BAC according to marital status. The most common profession was a skilled employee or junior salaried employee in a permanent employment relationship. The profile of the typical drunk driver did not change during the 18 years study period.

In 1996 a question on employment was added to the questionnaire. The number of male drunk drivers during the period 1996–2008 was 750. Employment information was received from 92.9% (697/750) of the subjects. The percentage of unemployed was 11.3 % (79/697) and the mean BAC was highest in this group (1.188 ‰, p=0.02).

Information on the class of driving license was received from 95.2 % (1079/1133) of male drunk drivers. The vast majority had a valid license (94.5 %). The figure is high compared to drunk drivers apprehended during ordinary police work. In this drunk driver population about one third in 2012 did not have a valid license [106].

The most common vehicle was a car and the figure for male drunk drivers was 80.1 %. About half of both male and female drunk drivers owned the vehicle in which they were tested. The most common annual driving distance was 20 000 – 50 000 km. Over half of the drunk drivers were alone in the vehicle. About one fourth had one passenger and one tenth 2–4 passengers. About one third of the male drunk drivers were either going to their workplace or had started from the workplace. There were fluctuations during the years, but no systematic trend (p=0.973). In 1995, 1997 and 2008 there were twice as many drunk drivers who were either on their way to the workplace or on their way home from the workplace compared to 1990. The results are presented in Table 4.

Table 4. The variation of male drunk drivers on their way to or from workplace (n=346, OR=odds ratio, CI=confidence interval, 1990 reference year)

Year	OR	95 % CI
1991	1.58	0.77–3.26
1992	0.86	0.42–1.75
1993	0.97	0.47–2.03
1994	1.19	0.58–2.44
1995	2.21	1.12–4.38
1996	1.32	0.68–2.59
1997	2.70	1.38–5.28
1998	0.81	0.39–1.66
1999	1.05	0.49–2.23
2000	0.87	0.41–1.82
2001	1.00	0.48–2.09
2002	0.68	0.34–1.38
2003	1.37	0.72–2.58
2004	0.99	0.49–2.02
2005	0.87	0.41–1.87
2006	1.98	0.56–7.03
2007	1.58	0.67–3.73
2008	2.57	1.04–6.34

Detailed information of both the profile and driving habits of drunk drivers is presented in Paper II.

It was thus demonstrated that the profile of a drunk driver did not change during the whole study period. The drunk driver was mostly a middle-aged man, married or cohabiting. Commonly he had a permanent employment relationship. The proportion of women varied only randomly.

A drunk driver in road-side studies in Finland was in the 1980's and early 1990's mostly a man with a mean age of 37.6 years. Only 6.9 % were women. The proportion of professional drivers was about 10 %. About 8 % of drunk drivers did not have a valid driving license [18]. In the present study the figure was somewhat lower (5.5 %). The mean age and the proportion of women seem to be at the same level as in the 1980's and early 1990's.

In other studies the drunk drivers in road-side surveys also seem to be mostly a middle-aged man. In a Canadian study the driver was a man in 78.4 % of the 1389 alcohol positive drivers [35]. Results from the DRUID study in Norway showed that alcohol as well as other drugs was more likely found in male drivers. Alcohol was more common in older age groups [28]. In the DRUID study in Denmark it was found that 89 % of alcohol positive drivers were men and the median age was 48 years (range 19–78 years) [30].

The Spanish DRUID study demonstrated that drunk drivers were more likely found as the age increased. A substance positive (alcohol and/or illicit drug) driver was more likely a man than a woman [33].

However, when compared to the profile of drunk drivers apprehended during ordinary police work, the profile of drunk drivers in the present study seems to be different in many respects. Among apprehended drunk drivers, there were more subjects in lower age groups (15–19 years) and more women [53].

5.3.2 Drivers who "had been drinking" (BAC < 0.50 ‰)

The majority of these drivers was men, in 87.8 % (2699/3075, information not recorded in 12 subjects). Thus the proportion of women was 12.2 % (376/3075). The proportion of women was highest at 17.7 % in 2006 and lowest at 4.6 % in 1998. There were fluctuations but no increasing or decreasing trend was found (p=0.029).

The mean age for men was 40.2 (SD±12.3) years (n=2660, information missing in 39 subjects). The mean age for women was 36.0 (SD±11.6) years (n=376, information missing in one subject). The mean age for men was statistically significantly higher than for women (p<0.0001).

The mean age for all subjects was lowest in 1990 (37.2; SD±11.0) and highest in 2008 (43.0; SD±12.5). The association between the age and the yearly study period was investigated by linear regression analysis, where age was the categorical variable and year the explanatory variable. It was demonstrated that the age had increased and the annual increase was 0.22 years (p<0.0001). Figure 6 shows the mean age±2SE (standard error).

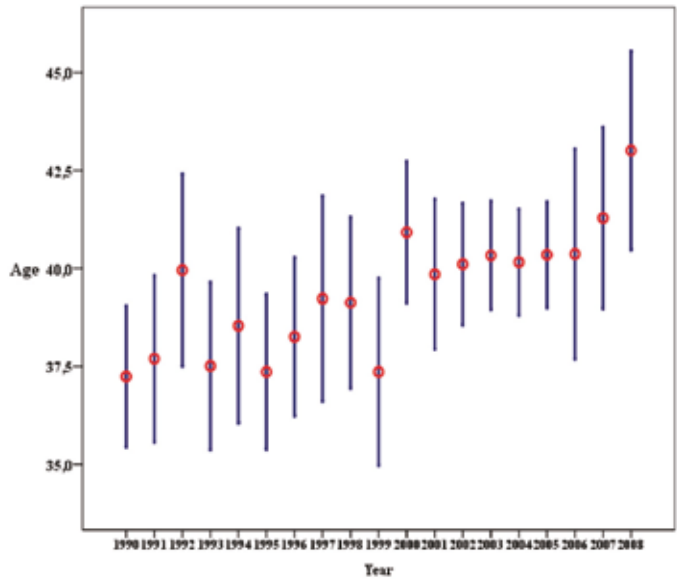

Figure 6. The mean age±2SE of drivers who "had been drinking" tested in 1990–2008.

During the same period also the age of the population in the Uusimaa area had increased, which partly may explain the finding.

Information on the marital status was received in 95.8 % of the subjects (2957/3087). The majority was either married (44.8 %) or cohabiting (28.2 %). There was no difference in the reading of the screening device according to marital status. The most common profession was a low-level salaried employee or professionally qualified worker in a permanent or casual relationship.

In 1996 a question on employment was added to the questionnaire. During the period 1996–2008 the number of drivers, who "had been drinking", was 2421. Employment information was received from 95.2 % (2306/2421) of the subjects. The percentage of unemployed was 4.7 % (109/2306). The mean reading of the screening device was highest in this group (0.263 ‰, p=0.03).

Information on the class of driving license was received in 97.3 % (3004/3087) of the drivers. The vast majority had a valid license (99.4 %). In 1980's and early 1990's 97.6 % had a valid license [18].

The most common vehicle was a car and the figure for male drunk drivers was 85.5 %. About two thirds of both male and female drivers owned the vehicle in which they were tested. The most common annual driving distance was 20 000 – 60 000 km. Over half of the drivers were alone in the vehicle. About one fourth had one passenger. About one fourth of the drivers were either going to their workplace or had started from the workplace. There were fluctuations during the years, but no systematic trend (p=0.077).

The profile of a driver who "has been drinking" has been estimated more often to resemble a drunk driver than a sober driver in a Finnish study in 1980's and early 1990's. It was concluded that the driver who "had been drinking" was a potential drunk driver [18]. In another Finnish study it was concluded that the driver who "had been drinking" resembled more the sober driver [59]. In the present study drivers, who "had been drinking" were grouped in drivers below 0.20 ‰, drivers between 0.20 and 0.49 ‰ and drunk drivers (≥ 0.50 ‰). It was shown that the two groups below 0.50 ‰ resembled each other more than the drunk drivers. It was thus concluded that a driver between 0.20 and 0.49 ‰ cannot be classified as a potential drunk driver.

5.4 Blood alcohol concentration

5.4.1 Blood alcohol concentration of drunk drivers

The mean BAC for men was 1.021 ‰ (SD±0.442, n= 1133) and for women 0.919 ‰ (SD±0.388, n=108). The BAC was found to be statistically higher among men than among women (p=0.02). The mean BAC for professional drivers was 1.005 ‰ (SD±0.443, n=107), but there was no difference in the mean between professional drivers and other male drunk drivers (p=0.700).

The annual mean BAC for men was at its lowest in 2004 (0.871 ‰, n=63) and at its highest in 2006 (1.199 ‰, n=16). The mean BAC varied only randomly and no increasing or decreasing trend was found (p=0.08). However, high individual BAC values were found.

The highest value, 3.51 ‰, was found during a Saturday morning session in 1994. The driver was a 34 year old man, who was on his way to the market. He had driven about 5 kilometers and he did not have a valid driving license. His marital status was 'cohabiting' and he was unemployed. He had no opinion on the risk for a drunk driver being caught.

The highest individual BAC value among women, 2.47 ‰, was also found during a Saturday morning session in 2007. The 40 year old woman had been driving about 10 kilometers and she was going to a visit. She was cohabiting and she had a permanent job. She estimated the risk for a drunk driver being caught as very high.

High individual blood alcohol concentrations were found also in drunk in drivers going to work or on their way home from the workplace.

In 2008 a 49 year old man, decorator by profession, was on his way from the workplace during Tuesday afternoon. His BAC was 2.17 ‰ and he had driven 35 km before the survey spot. He had one passenger in the car, which he did not own. He estimated the risk for a drunk driver being caught as high.

A 42 year old entrepreneur was caught during a Saturday morning survey in 2003 when he was on his way to work. His BAC was 2.35 ‰ and he had driven 2 km. He drove a lorry and he estimated the risk of being caught as moderate.

The mean BAC did not differ between spring and autumn. However, the mean BAC was at highest during Saturday night session (1.193 ‰). In Table 5 the mean BAC, SD, IQR and number drivers tested during different time periods are presented.

Table 5. Mean BAC, SD, IQR and number drivers tested during different time periods (n=1241, both men and women)

Time	Mean BAC,‰	SD	IQR[1]	≥0.50 ‰,n	Drivers tested[2]
Spring	1.023	0.423	0.540	602	271603
Autumn	1.002	0.453	0.530	639	270892
Tue 7–11 a.m.	0.974	0.389	0.450	234	137209
Tue 4–6 p.m.	1.077	0.490	0.600	98	95400
Tue 9 p.m.–1 a.m.	1.075	0.459	0.640	137	69044
Sat 8 a.m.–1 p.m.	0.938	0.395	0.410	571	161627
Sat 9 p.m.–1 a.m.	1.193	0.509	0.840	201	79215
Totally				1241	542495

[1] Interquartile range.
[2] The number includes all breath–tested drivers during the time period.

The mean BAC was at highest in the age group 40–44 years. In Table 6 the results are presented in detail.

Table 6. Mean BAC, SD and range according to age class (men, n=1132[1])

Age class	Mean BAC, ‰	SD	Range,‰
< 20	0.760	0.298	0.57–1.80
20–24	0.993	0.388	0.50–2.02
25–29	1.013	0.435	0.52–2.30
30–34	1.022	0.483	0.51–3.51
35–39	0.962	0.389	0.53–2.35
40–44	1.088	0.493	0.50–3.33
45–49	1.036	0.443	0.50–2.44
50–54	1.058	0.439	0.51–2.40
55–59	1.053	0.478	0.51–2.90
60–64	0.906	0.312	0.55–2.01
65–	0.934	0.366	0.51–1.85
Totally	1.021	0.442	0.50–3.51

[1]Information missing in 1 subject

The mean BAC was at highest for men (n=1133) during the Saturday night session (1.210 ‰). The mean BAC for men was 0.23 ‰ higher compared to Tuesday morning (0.971 ‰). Both the time of the survey and the age from 40 to 59 years predicted higher BAC as shown in Table 7.

Table 7. Predictive factors for the BAC based on linear model (men, n=1133)

Variable	Estimate, ‰	SE	t-value	p
Time				
Spring/autumn	-0.049	0.03	-1.82	0.07
Tue 4–6 p.m.	0.044	0.06	0.75	0.45
Tue 9 p.m.–1 a.m.	0.085	0.06	1.49	0.14
Sat 8 a.m.–1 p.m.	-0.03	0.04	-0.74	0.46
Sat 9 p.m.–1 a.m.	0.232	0.05	4.40	<0.0001
Age class				
20–24	0.123	0.12	1.00	0.32
25–29	0.171	0.12	1.42	0.16
30–34	0.168	0.12	1.42	0.16
35–39	0.153	0.12	1.31	0.19
40–44	0.300	0.12	2.58	0.01
45–49	0.286	0.12	2.45	0.01
50–54	0.286	0.12	2.41	0.02
55–59	0.264	0.12	2.14	0.03
60–64	0.165	0.13	1.26	0.21
65–	0.136	0.14	0.97	0.33

Regardless of individual high BAC concentrations, the overall mean BAC in drivers in road-side surveys (1.012 ± 0.439 ‰, n=1241) is considerable lower than the mean BAC in apprehended drunk drivers (1.62 ‰) [53]. In road-side studies from the 1980's and early 1990's the mean BAC±SD was 1.06 ± 0.46 ‰, i.e. at the same level as during the time period in the present study [18]. In fatal traffic accidents involving drunk driving during 2009–2011 in Finland the mean BAC was 1.89 ‰ (n= approx. 70), [107].

5.4.2 The impact of changes in the legislation and the taxation

The limit of aggravated drunk driving was lowered in 1994 from 1.5 ‰ to 1.2 ‰. In March in 2004 the taxation of alcohol beverages was reduced about 30 %. As shown in Tables 8 and 9, neither action affected the mean of the BAC (p=0.630) nor the percentage distribution of the BAC.

Table 8. The BAC distribution calculated as a percentage before and after the change in legislation

Time period	0.50–1.19 ‰	1.20–1.49 ‰	≥ 1.50 ‰	n
before1.9.1994	72.6	15.1	12.3	325
after 1.9.1994	73.5	13.0	13.5	916
Totally				1241

Table 9. The mean BAC between different time periods according to alcohol policy actions

Time period	BAC, ‰(SD)	n
1990–1994	1.022 (0.410)	325
1995–1999	1.000 (0.430)	382
2000–2003	1.000 (0.461)	310
2004–2008	1.035 (0.463)	224
Totally		1241

Detailed information on the BAC in relation to all parameters is presented in Paper II.

5.4.3 Blood alcohol concentration for drivers who "had been drinking (BAC ≤ 0.50 ‰)

The mean of the result of the screening device was for men 0.235 ‰ (SD±0.143, n=2686; not recorded in 10 subjects) and for women 0.214 ‰ (SD±0.132, n=374, not recorded in 2 subjects). The mean was statistically significantly higher among men (p=0.005).

The association between the age and the result of the screening device was investigated by linear regression analysis, where age was the categorical variable and the result of the screening device was the explanatory variable. It was demonstrated that there was no difference in the result of the screening device according to the age (p=0.151).

The association between the result of the screening device and the annual study period was also investigated by linear regression analysis. The result of the screening device was the categorical variable and the year was the explanatory variable. It was demonstrated that the result of the screening device began to decrease in 1999. The annual decrease was 0.00476 ‰ (95 % CI 0.00378 ‰ – 0.00573 ‰; p<0.0001). The detailed results are presented in Table 10.

Table 10. The annual relative proportion of the two groups of the result of the screening device (OR=odds ratio, CI=confidence interval, n=3069, result not recorded in 18 subjects)

Year	Totally n	0.01–0.19 ‰ n	Proportion %	0.20–0.49 ‰ n	Proportion %	OR	95 % CI
1990	146	39	26.71	107	73.29	1.00	reference
1991	104	25	24.04	79	75.96	1.15	0.65–2.07
1992	95	15	15.79	80	84.21	1.94	1.02–3.86
1993	110	22	20.00	88	80.00	1.46	0.81–2.67
1994	88	19	21.59	69	78.41	1.32	0.71–2.51
1995	119	35	29.41	84	70.59	0.87	0.51–1.50
1996	137	32	23.36	105	76.64	1.20	0.70–2.06
1997	96	25	26.04	71	73.96	1.04	0.58–1.87
1998	110	35	31.82	75	68.18	0.78	0.45–1.35
1999	112	44	39.29	68	60.71	0.56	0.33–0.95
2000	179	71	39.66	108	60.34	0.55	0.34–0.89
2001	171	66	38.60	105	61.40	0.58	0.36–0.93
2002	264	135	51.14	129	48.86	0.35	0.22–0.54
2003	323	208	64.40	115	35.60	0.20	0.13–0.31
2004	330	196	59.39	134	40.61	0.25	0.16–0.38
2005	362	203	56.08	159	43.92	0.29	0.19–0.43
2006	84	38	45.24	46	54.76	0.44	0.25–0.77
2007	142	81	57.04	61	42.96	0.27	0.17–0.45
2008	97	45	46.39	52	53.61	0.42	0.24–0.72

5.5 Risk factors for DUI driving

The risk factors were calculated based on the comparison material consisted of 3407 drivers in 1998–2000. The reading of the screening device was negative in these subjects. Altogether during these surveys 32689 drivers were tested. The number of drivers who "had been drinking", i.e. (< 0.50 ‰) was 403 and the number of drunk drivers 88.

5.5.1 Risk factors for alcohol positive driving (BAC < 0.50 ‰)

The most reliable explanatory factors were the time of the survey (weekday and time) and the gender. The most probable time to catch a driver, who "had been drinking" was on Saturday from 9 p.m.–1 a.m. The risk was about threefold compared to Tuesday from 7–11 a.m. ($p < 0.0001$). During Saturday morning and Tuesday afternoon the risk was about 2.5 fold compared to Tuesday morning ($p<0.02$ and $p<0.002$).

The risk of driving for women who "had been drinking" was one third of that for men. When there were several factors considered at the same time in the analysis the risk for the age groups '35–44 years' was twice as high and the age group '50–54 years' almost three times as high compared to the age group 'below 20 years'. The risk for divorced people was almost twice as high as for married drivers ($p<0.0001$).

Some other explanatory risk factors were also found. If the driving event at the survey was related to the profession of the driver his risk was three times higher compared to driver, whose driving event was not related to his profession. The class of the driving license was also found to impact the risk. If the driving event was related to the profession of the driver and he had a license belonging to the group 1 (i.e. a taxi driver), the risk for driving with a BAC below 0.50 ‰ was higher than for a professional driver, whose license belonged to group 2 (i.e. a trucker). The result of the analysis is presented in detail in Table 11.

Table 11. Risk factors for driving below 0.50 ‰ based on comparison sober subjects (n= 3407). Odds ratios with 95 % confidential limits based on logistic regression model

Variable	OR	95 % CI
Time of survey		
Tue 7–11 a.m.	reference	
Tue 4–6 p.m.	1.29	0.82–2.02
Tue 9 p.m.–1 a.m.	2.44	1.65–3.62
Sat 8 a.m.–1 p.m.	2.36	1.68–3.33
Sat 9 p.m.–1 a.m.	3.58	2.43–5.28
Gender		
Male	reference	
Female	0.32	0.23–0.45
Marital status		
Married	reference	
Unmarried	0.96	0.69–1.32
Cohabiting	1.35	0.98–1.85
Divorced	1.77	1.24–2.54
Widowed	1.98	0.84–4.68
Age class, year		
< 20	reference	
20–24	1.69	0.83–3.45
25–29	1.93	0.92–4.04
30–34	1.80	0.86–3.75
35–39	2.36	1.14–4.86
40–44	2.11	1.00–4.44
45–49	2.05	0.96–4.38
50–54	2.72	1.29–5.73
55–59	1.38	0.61–3.14
60–64	0.83	0.33–2.08
65–	0.40	0.13–1.29
Ownership of the vehicle		
Own	reference	
Not own	1.07	0.85–1.35
Vehicle		
Car	reference	
Other	0.64	0.46–0.87
Class of driving license		
A,B BE	reference	
C,CE,D and DE	0.78	0.62–0.98
Driving event related to the profession		
no	reference	
yes	3.35	1.91–5.90

5.5.2 Risk factors for drunk driving (BAC≥0.50 ‰)

The most reliable explanatory factors for drunk driving were the time of the survey (weekday and time) and the gender. The most probable time to catch a drunk driver in the traffic flow was on Saturday from 8 a.m.–1 p.m. The risk was about threefold compared to Tuesday from 7–11 a.m. and about eight times higher compared to Tuesday from 4–6 p.m. The day and the time of the survey were also found to be predictive factors for higher BAC ($p < 0.0001$).

The risk of drunk driving for women was less than one fifth that for men. Divorcees and widow(er)s also had a substantially higher risk of being caught drunk driving than married drivers. The risk for divorced drivers was notably higher when there were several factors considered at the same time in the analysis. In this model the risk was found to be over ten times higher compared to married drivers. If the marital status was taken separately in the model, the risk for drunk driving was twice as high for divorced drivers compared to married drivers. For widowed drivers the risk was over threefold in both models.

Age as such was not found to be a risk factor. However, if there were several factors at the same time in the analysis, the age group '30–54 years' had a two-fold higher risk for drunk driving compared to the age group 'below 20 years'.

The result of the analysis is presented in detail in Table 12.

Table 12. Odds ratios and 95 % confidence intervals based on three types of logistic regression models. Model 1 is univariate model, Model 2 includes all explanatory variables in the same time, Model 3 is multivariate model based on stepwise selection procedure. Sober drivers are the comparison subjects.

Variable	Estimate			Drunk drivers	Comparison subjects
Time of survey	**Model 1**	**Model 2**	**Model** 3	n	
Tue 7–11 a.m.	reference			8	6821
Tue 4–6 p.m.	0.41	0.34	0.42	2	4180
	(0.09–1.93)	(0.06–1.86)	(0.09–1.99)		
Tue 9 p.m.–1 a.m.	1.14	0.72	0.96	5	3612
	(0.37–3.48)	(0.19–2.80)	(0.31–2.96)		
Sat 8 a.m.–1 p.m.	3.52	4.48	3.12	45	10936
	(1.66–7.47)	(1.83–10.96)	(1.47–6.65)		
Sat 9 p.m.–1 a.m.	1.58	0.82	1.57	6	3116
	(0.55–4.54)	(0.21–3.27)	(0.54–4.54)		
Gender					
Male	reference			63	21383
Female	0.14	0.06	0.06	3	7282
	(0.04–0.44)	(0.02–0.25)	(0.05–0.51)		
Marital status					
Married	reference			27	15835
Unmarried	1.63	1.86		18	6428
	(0.89–2.95)	(0.42–0.09)			
Cohabiting	1.48	2.80		10	3954
	(0.72–3.06)	(0.97–0.31)			
Divorced	2.49	10.97		8	1882
	(1.13–5.49)	(3.12–1.47)			
Widowed	3.12	3.27		3	566
	(0.94–10.31)	(1.57–0.54)			
Age class, year					
< 20	reference			3	774
20–24	0.4	0.59		4	2648
25–29	0.09	0.24		1	2799
30–34	0.96	2.47		13	3570
		(0.62–9.85)			
35–39	0.53	1.49		8	3942
40–44	0.75	2.92		10	3539
		(0.66–12.85)			
45–49	0.77	2.22		9	3094

		(0.48–10.19)			
50–54	0.85	2.68		11	3396
		(0.58–12.24)			
55–59	0.26	0.47		2	2056
60–64	0.56	0.47		3	1418
65–	0.37	0.31		2	1429

5.5.3 Drivers who "had been drinking" compared to drunk drivers

The risk factors were calculated based on all subjects during the study period, 1241 drunk drivers and 3087 drivers, who "had been drinking".

The risk for drunk driving was lowest at Tuesday 9 p.m. –1 a.m. and Saturday 9 p.m. –1 a.m. The risk was half that of the risk at Tuesday morning (7 a.m. –11 a.m.; $p<0.0001$). The risk for a man who "had been drinking" to be a drunk driver was three times higher than for a woman, who "had been drinking". Divorced drivers were more common in drunk drivers. Age did not impact either group of drivers. If all background facts were included in the model, the proportion of drivers who did not have a valid license was fivefold among drunk drivers ($p< 0.0001$).

The results are presented in detail in Table 13.

Table 13 . Risk factors for driving below 0.50 ‰ based on comparison to drunk drivers. Odds ratios with 95 % confidential limits based on logistic regression model

Variable	OR	95 % CI
Time of survey		
Tue 7–11 a.m.	reference	
Tue 4–6 p.m.	0.60	0.43–0.83
Tue 9 p.m.–1 a.m.	0.45	0.33–0.59
Sat 8 a.m.–1 p.m.	0.78	0.63–0.97
Sat 9 p.m.–1 a.m.	0.46	0.35–0.61
Gender		
Male	reference	
Female	0.69	0.53–0.90
Marital status		
Married	reference	
Unmarried	1.23	0.98–1.54
Cohabiting	1.02	0.80–1.30
Divorced	1.72	1.38–2.15
Widowed	1.55	0.73–3.16
Age class, year		
< 20	reference	
20–24	1.16	0.63–2.26
25–29	1.18	0.64–2.30
30–34	1.72	0.93–3.33
35–39	1.61	0.87–3.13
40–44	1.76	0.95–3.43
45–49	1.78	0.96–3.47
50–54	1.52	0.80–3.01
55–59	1.54	0.79–3.13
60–64	1.52	0.74–3.23
65–	1.86	0.84–4.17
Ownership of the vehicle		
Own	reference	
Not own	1.18	1.01–1.38
Class of driving license		
A,B BE	reference	
C,CE,D and DE	0.92	0.78–1.07
Professional driving		
no	reference	
yes	1.09	0.73–1.63

5.5.4 Comparison between drivers below 0.20 ‰, between 0.20–0.49 ‰ and drunk drivers

The purpose was to find out if there was a difference between these two groups of drivers and if the driver in the group 0.20–0.49‰ resembled drunk driver. According to the reading of the screening device, the two groups were drivers below 0.20 ‰ (n= 1333) and between 0.20 and 0.49 ‰ (n=1736). Between the groups the proportion of men and women did not differ. However, there were more men in the drunk driver category. There were about three times more drivers in the age group '60 years or older' among below 0.20 ‰ drivers compared to drivers between 0.20 and 0.49 ‰. The marital status did not differ between the drivers below 0.20 ‰ and between 0.20 and 0.49 ‰, but in the drunk drivers group there were about twice as many divorced people.

In drunk drivers there were about three times more unemployed people compared to drivers between 0.20 and 0.49 ‰ and in the group below 0.20 ‰ were half as many unemployed compared to drivers between 0.20 and 0.49 ‰.

In the two groups of drivers below 0.20 ‰ and between 0.20–0.49 ‰ more similarities than differences were found. Both groups were similar in terms of gender and marital status. The percentages of men, of divorcees and of unemployed persons were considerably lower in the groups of drivers between 0.20–0.49 ‰ than in the group of drunk drivers. It is thus not a valid conclusion to deduce from this profile that a driver between 0.20–0.49 ‰ is a potential drunk driver.

Detailed results are presented in Table 14.

Table 14. Comparison between the two groups of drivers who "had been drinking" and drunk drivers. Drivers in the group between 0.20–0.49 ‰ is the reference group

Variable	BAC< 0.20 ‰		BAC ≥0.50 ‰	
	OR	95 % CI	OR	95 % CI
Time of survey				
Tue 7–11 a.m.	reference			
Tue 4–6 p.m.	1.75	1.19–2.57	0.60	0.35–1.04
Tue 9 p.m.–1 a.m.	2.08	1.48–2.93	0.45	0.27–0.72
Sat 8 a.m.–1 p.m.	0.94	0.70–1.28	0.77	0.53–1.12
Sat 9 p.m.–1 a.m.	2.33	1.66–3.28	0.56	0.35–0.89
Gender				
Male	reference			
Female	1.09	0.84–1.42	0.59	0.40–0.89
Marital status				
Married	reference			
Unmarried	0.80	0.27–2.33	280.69	131.89–597.35
Cohabiting	0.85	0.64–1.14	6.71	4.83–9.31
Divorced	1.01	0.80–1.28	1.86	1.33–2.62
Widowed	1.25	0.97–1.61	0.34	0.18–0.65
Age class, year				
< 20	reference			
20–24	1.76	0.90–3.46	1.14	0.51–2.55
25–29	1.57	0.79–3.14	1.26	0.55–2.89
30–34	1.94	0.96–3.92	1.83	0.79–4.24
35–39	1.96	0.97–3.97	1.45	0.63–3.35
40–44	1.62	0.80–3.30	1.40	0.60–3.24
45–49	1.84	0.90–3.74	1.28	0.55–2.98
50–54	1.62	0.79–3.34	0.75	0.31–1.79
55–59	1.84	0.87–3.88	0.62	0.24–1.60
60–64	2.61	1.13–6.01	0.47	0.15–1.44
65–	3.56	1.30–9.74	0.61	0.15–2.39
Passengers				
yes	reference			
was alone	0.90	0.75–1.08	1.01	0.78–1.30
Purpose of the drive				
not to/from work	reference			
to/from work	0.82	0.65–1.02	0.94	0.69–1.30

Professional driving				
no	reference			
yes	0.66	0.39–1.15	1.12	0.60–2.10
Employment				
permanent	reference			
periodic	1.12	0.80–1.58	1.44	0.92–2.25
student	1.32	0.82–2.14	1.25	0.66–2.36
unemployed	0.53	0.34–0.83	3.08	2.01–4.71
retired	0.63	0.35–1.13	1.01	0.45–2.26

In earlier studies of drunk drivers in roadside surveys in Finland it has been concluded that a great many drivers, who "had been drinking" actually belong to the drunk drivers group although the BAC at that time did not exceed the legal limit [18]. In another study it was demonstrated that the drivers who "had been drinking" resembled sober drivers more than the drunk drivers in that connection [59]. In the present study the number of subjects and the methods used for analysis support the conclusion that a driver, who "has been drinking" is not a potential drunk driver.

5.6 Risk factors for recidivism

5.6.1 Impact of biomarkers and previous conviction for DUI

In the long-term study of the drunk drivers in Uusimaa the biomarkers GGT, CDT and their mathematical combination, the index γ-CDT, was investigated in a pilot group of alcohol positive drivers (n=237) in 1996 and 1997. Of these drivers, 132 had a BAC ≥0.50 ‰. The same concept was applied to another pilot group of drunk drivers apprehended during ordinary police work in the greater Helsinki area (n=193). Of these drivers 173 had a BAC ≥0.50 ‰. These drivers were investigated at the forensic medical station of the University of Helsinki.

In the RBT drivers group the level of the biomarkers was significantly lower if the BAC was below 0.50 ‰. The index γ-CDT showed a stronger significance for drunk driving than either biomarker alone. In the group of apprehended alcohol positive drivers neither of the biomarkers showed significant outcome for drunk driving. The results are described in detail earlier (paper I).

The data of drivers included into the computer run of DUI recidivism are shown in Table 15. The subjects were further grouped according to the blood alcohol concentration because the degree of drunk driving was also evaluated as a possible risk factor for recidivism. Recidivism was investigated both retrospectively from 1990 to 1996/1997 and prospectively from 1996/1997 to 2006.

Table 15. Data of drivers included into the computer run of DUI recidivism

	RBT drivers[1] (n, %)	Apprehended drivers[2] (n, %)
BAC ≥ 0.50 ‰	99 (75.0%)	61 (35.3%)
BAC ≥ 1.20 ‰	33 (25.0%)	112 (64.7%)
γ-CDT[3]		
< 6.5	10 (7.6 %)	22 (12.7 %)
≥ 6.5	122 (92.4 %)	149 (86.3 %)
Age, years < 30	17 (12.9 %)	64 (37.0 %)
30-40	49 (37.1 %)	44 (25.4 %)
41-50	41 (31.1 %)	36 (20.8 %)
> 50	25 (18.9 %)	29 (16.8 %)
DUI before[4], yes	35 (26.5 %)	64 (37.0 %)
DUI before, no	97 (73.5 %)	109 (63.0 %)
Totally	132	173

[1] Drunk drivers during random breath testing surveys (RBT)
[2] Drunk drivers apprehended during ordinary police work.
[3] γ-CDT= 1.35 x ln CDT+0.8 x ln GGT, <6.5 U/l.
[4] At least one sentence of drunk driving before the time of capture in this study.

For RBT drunk drivers it was demonstrated that the risk for DUI recidivism was 1.3 times higher if the index γ-CDT was ≥ 6.5 U/l compared to a level below 6.5 U/l. However, in apprehended drunk drivers the index was not found to be a statistically significant estimate for DUI recidivism.

It was found that one third of RBT drivers in the pilot group reoffended at least once during the following ten years (1996/1997–2006). Of the 132 drunk drivers, 66 had been caught for drunk driving only once during the study period 1990–2006. During the study period 33 drivers had reoffended twice. The rest 33 drivers had reoffended between 3 and 24 times. The highest individual BAC was 2.07 ‰.

In the study it was calculated that the risk for DUI recidivism for RBT drivers was 3.3 higher if the driver had at least one sentence of drunk driving before the capture time in 1996/1997 compared to drivers with no earlier conviction for drunk driving. Additionally it was demonstrated that the risk for recidivism increased 2.5 times for drunk drivers with a BAC above 1.20 ‰ at the time of the offence compared to drunk drivers with a lower BAC.

In the drunk drivers apprehended during ordinary police work (n=173), 74 drivers were reoffended at least once during the following ten years (1996/1997–2006). The risk for DUI recidivism was found to be 5.0 higher if the driver had at least one previous conviction for drunk driving compared to those who had none. The BAC was not a significant predictor of outcome in this group of drivers.

It was thus shown that there were both similarities and differences between the two groups of drunk drivers. The apprehended drunk drivers did not show a significant relationship between γ–CDT and DUI recidivism and neither did the level of

BAC predict recidivism. The two groups of drivers represent different population of drunk drivers as also have been shown in earlier studies. However, the rate of recidivism was at a similar level in roadside drunk drivers and apprehended drunk drivers. The rate had not changed during 30 years, still about one third of drunk drivers repeat the offense [18,19,53].

6 Conclusions

In the province of Uusimaa in southern Finland the prevalence of drunk driving did not change between 1990 and 2008. One in every 500 drivers was a drunk driver. The prevalence, 0.2 %, has varied only randomly. The mean BAC, (1.021 ‰ for men and 0.919 ‰ for women) did not change during the study period. The legal limit for aggravated drunk driving was lowered in 1994 from 1.5 to 1.2 ‰. In 2004 taxation on alcohol beverages was lowered by about 30%. No evidence of an impact from these events either on the prevalence of drunk driving or on the mean BAC of drunk drivers was found. The prevalence seems to be somewhat higher than in Sweden and Norway but compared to figures from European Union, Canada and USA the prevalence in Finland is at a lower level. However, it is difficult to reliably compare the figures due to variable study designs, different legal limits and matrixes for determination of the alcohol concentration.

The prevalence of drivers who "had been drinking" was about 0.4 % in the 1990's. The level began to increase in the early 2000's and peaked at 1.11 % in 2005. After that the prevalence has varied around 0.6–0.8 %. The increase can at least partly be explained by higher alcohol consumption.

In the early 1990's it has been estimated that the risk for a drunk driver in Finland of being caught is about 1:100–1:300 during a 30 km drive [19]. The estimate in the present study was at the same level (1:227, paper II), which suggests that the risk has not changed throughout the years. It was also calculated that in 2008 there were daily 3460 and annually 1.26 million drunk driving events in Uusimaa (papers II and III). The "dark figure" of drunk driving seems still to be very high and shows that only a small percentage of drunk drivers are caught by the police.

The design of the present study made it possible to evaluate risk factors for driving under influence of alcohol. Risk factors were evaluated both for drunk drivers (BAC ≥ 0.50 ‰) and for drivers, who "had been drinking" (BAC< 0.50 ‰). Risk factors for DUI recidivism were also investigated.

High risk factors for drunk driving were the time of the survey and the gender of the driver. The risk on a Saturday morning was about eight times higher than during Tuesday afternoon. The risk for a female to drive drunk was less than a fifth that of men. Divorced and widowed people had a clearly higher risk than married drivers. In the age group '30–54 years' the risk for drunk driving was higher compared to the age group 'below 20 years'. High blood alcohol concentrations were found during weekday morning and early afternoon, which is a sign of problem drinking. Unemployed drunk drivers had also higher blood alcohol concentration. Attention should thus be paid to the drunk driver also as an individual.

Risk factors for driving with a BAC below 0.50 ‰ were also the time of the survey and the gender of the driver. The risk was three times higher to catch a driver who "had been drinking" during Saturday evening and night compared to Tuesday morn-

ing. The risk for a female was one third of that for a male. Divorced people had almost twice as high risk than married drivers.

Risk factors for DUI recidivism were an elevated level of the biomarker index γ–CDT and a BAC of ≥ 1.20 ‰. A notable risk factor was also an earlier conviction of drunk driving and the marital status (paper I). The findings justify an obligatory use of alcolocks as one preventive measure to counteract recidivism. The use of alcolocks should be more efficiently expanded in Finland. The cost of an alcolock is about 1300–2000 euro's and the shortest period is one year. Studies from f.i. Sweden, Canada and USA have shown good results of the impact of alcolocks on recidivism [108-112]. Roughly one third of drunk drivers in Finland repeat the offense. The rate has not changed during 30 years [18,43,50,53].

The present long-term Finnish study is unique worldwide. The commitment to the work by the National Traffic Police and the research team has made it possible to keep the concept at a high level. The results of the prevalence of drunk drivers and drivers who "have been drinking" can thus be considered both comparable and reliable over time. The extensive information on the profile and driving habits of the drivers is exhaustive, which partly depends on that the Finnish driver is cooperative. It is important to continue and develop the concept for studies on drunk driving and to maintain the compatibility with results from earlier studies. The RBT method is regarded as the only sufficiently reliable method for monitoring the prevalence of drunk driving [15,19,113].

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