HEALTHY DRIVING: A STUDY OF DRIVERS' HEALTH CONDITION AND RELATIVE CRASH RISK

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ABSTRACT

It is required that drivers have to be sufficiently fit to drive in a safe manner, and several countries, among them Norway, have specified various health requirements that need to be met in order to hold a driver's licence. This implies that diseases and health conditions may have an effect on driving behaviour and involvement in accidents. Whereas research on health conditions and driving behaviour and/or accident risk first and foremost have been related to specific driver groups (in particular elderly drivers), research on diseases and health conditions among *all drivers* are rare. Moreover, results from such studies are diverging, and confounding factors are seldom controlled for. In the present study, accident risk among 4307 respondents was estimated for various self-reported diseases and general health conditions. The study is a replication of a similar study conducted 4 years earlier, and in both studies accident risk was measured by means of quasi-induced exposure in multiple vehicle accidents. Analyses of accident risk were performed for each risk factor (i.e., the various diseased and health conditions). In addition, a logistic regression was performed in which possible confounding variables such as age, sex, and annual driving exposure were controlled. The results show that, when controlling for confounding factors, the following variables were associated with increased accident risk: general tiredness (OR=1.81, $p<0.001$), having experienced a stroke (OR=2.61, $p<0.05$) and strong visual impairment on one eye (OR=2.42, $p<0.001$).

1. INTRODUCTION

In most countries, in order to obtain and hold a driver's license, certain health requirements have to be met (Vaa 2003). The specific health conditions, and who is responsible for reporting these health conditions to the driving licensing bureaus, varies between countries (Vaa 2003). Nevertheless, there is an underlying assumption that certain physical and mental conditions reduce people's ability to drive and that this reduced driving ability in turn is associated with increased accident risk. The present study is a replication of a study on accident risk associated with various health conditions conducted in 2003 in Norway.

Increased accident risk for various diseases have been documented previously (Charlton et al. 2004; Sagberg 2006; Vaa 2003). Among diseases that have been found to increase accident risk for drivers are migraine (Norton et al. 1997), hypertension (Hours et al. 2008), Parkinson's disease (Klimkeit et al. 2009), diabetes (Vernon et al. 2002) and yet other diseases and health conditions (Vaa 2003).

There are, however, some limitations in the studies on accident risk and health conditions. First, such studies tend to be conducted among elderly (Alvarez and Fierro 2008; Lam and Lam 2005; McGwin et al. 1998; McGwin, Jr. et al. 2000; Meuser et al. 2009) as prevalence of various diseases and impairments increase with age. Second, as pointed out by Vaa (2003) such studies often fail to control for potential confounding factors. In the present project, accident risk of drivers with various health conditions were estimated in a sample of drivers including both young and elderly respondents. Moreover, relative risk estimates were conducted controlling for potential confounding factors such as age, sex, and exposure, as well as other diseases and health conditions.

In addition, in the present study we also investigate accident risk associated with various self-reported health plagues. More specifically, these are health conditions that most often are not diagnosed by medical doctor, nor medicated, but that may still affect driving ability and accident risk, for instance sleep-related problems and mild psychological distress. Previous studies have found increased accident risk associated with sleepiness (Connor et al. 2002; Sagberg 2006), while results for depression and general psychological distress are inconclusive (Charlton et al. 2004; Vingilis and Wilk 2008).

Finally, various visual and hearing impairments, as well as medication use were investigated as potential risk factors in the present study. Importantly, all health conditions studied in this project (i.e., all diseases, health impairments, and medication use) are included based on empirical or theoretical reasoning.

Thus, the main aim of the present study was to investigate accident risk for various health impairments, diseases and medication use[1]. More specifically, the following research problems were addressed:

[1] "Health condition" is in the present article used as a collective term for diseases, health impairments (including visual and hearing impairments), and medication use.

1. Are drivers who suffer from diseases at increased accident risk?
2. Are drivers who experience health impairments at increased accident risk?
3. Are drivers who use medication at increased accident risk?

Although the risk factors as they appear in the research problems are formulated in a general sense (e.g., diseases), a set of specific diseases are tested, as is the case with health impairments and medications.

2. METHODS

2.1. Sample and procedure

33 103 drivers who had been involved in an accident during 2006 received invitation by post mail to participate in a web based survey on various risk factors in traffic. The sample of accident involved drivers was drawn by a Norwegian insurance company (Gjensidige), and the invitation letters were signed both Gjensidige and The Institute of Transport Economics.
6111 persons participated in the study. This means a response rate of 18 percent, which is far lower than expected. As for the response rate, several points are worth noting: First, low response rates of about 25 to 30 % are not unusual in Norway at present. One likely explanation is the constant "overload" of invitations that inhabitants in Norway receive either by e-mail, post mail or telephone, to participate in both marketing and research surveys. Second, the low response rate in this survey can probably also be explained by the specific sample of accident involved drivers combined with the facts that the survey topic was traffic risk factors and people were approached by their own insurance company. Although anonymity and confidentiality was explicitly assured[2], we cannot rule out that respondents felt threatened by being asked – by their insurance company in which they had reported a specific accident – about risk factors in traffic. Thus, perception of the content of the survey as being sensitive and threatening can be one explanation of the low response rate in this survey. Third, we experienced some problems with the web-solution during the data-gathering, with respondents not being able to access the web-page. We received several complaints regarding this issue. All these were met with guidance after which all who had made a complaint were able to access the survey. However, there were probably many potential respondents who experienced similar problems but who did not contact us, and consequently did not answer the survey. This may have contributed to the low response rate. It is worth noting, though, that this potential explanation would "hit" randomly, and no systemic bias would appear because of this limitation.

[2] The project was approved by the Norwegian Social Science Data Services.

Because of the low response rate, we conducted analyses to examine potential responder bias. The analyses showed that the following driver groups were under-represented in our study sample compared to the gross sample (i.e., those who received invitation letters): a) males (61 % vs. 64 %), b) young drivers (Mean age in study sample=48 vs. Mean age in gross sample=47) and c) at-fault drivers (54 % vs. 62 %). Although these differences between the study sample and the gross sample were statistically significant, it is important to note that they are rather small.

Although this primarily was a web-based survey, participants were given the opportunity to inquire a regular paper-version of the questionnaire if they were unable to respond on the internet. As predicted, this option was first and foremost used by elderly participants (466 persons, of which only 8 % were under the age of 50, whereas 50 % were older than 72 years).

It was estimated that it would take approximately 20 minutes to complete the survey, and respondents were informed that they could win a traveller's cheque if they completed the questionnaire.

2.2. Measures

Each invitation letter referred to a specific accident that the recipient of the letter had been involved in during 2006, and participants were instructed to answer the survey thinking about that specific accident. The survey covered the following themes that are of relevance in the present study: a) frequency of health impairments, b) chronic disease at the time of the accident, c) medicine use at the time of the accident, d) visual-, hearing,- and movability-impairments, e) culpability of the accident, f) type of accident, g) exposure and h) other relevant background variables (for more information about measures, see appendix).

Importantly, culpability of the accident (i.e., whether the driver was at-fault or not-at-fault in the accident) was measured by means of self-report ("According to the insurance company, who was responsible for the accident?" I myself/ The other part/ Shared responsibility). Self-report measures covering sensitive topics such as culpability of an accident may generate false answers. However, as we asked about the *insurance company's* decision about culpability, we believe there is no reason for giving a false answer. Moreover, in order to let the respondent state *his or her* subjective experience of the accident, the next question in order was "In your opinion, what was the most important cause of the accident?" Respondents were to answer in a free text field.

2.3. Induced exposure

Of the 6111 participants in the study, data from 4307 people were usable for the present analyses. This is due to the fact that we only include multiple vehicle accidents in the analyses when we estimate relative risk by means of induced exposure.

When lacking information about exposure of a specific risk factor in traffic, one way to estimate accident involvement related to the risk factor is by means of so called quasi-induced exposure (Stamatiadis and Deacon 1997). Quasi-induced exposure leans upon the presumption that the prevalence of a risk factor, in this case various health conditions, is the same among non-responsible drivers in multiple-vehicle accidents as in the driver population in general. Thus, if the percentage of a health condition among responsible drivers in multiple-vehicle crashes is higher than the percentage of the same health condition among non-responsible drivers, it can be concluded that suffering from this health condition increases accident risk. The relative risk equals the ratio of this health condition among responsible drivers to this health condition among non-responsible drivers (Sagberg 2001). In other words, at-fault drivers with the risk factor present are equivalent to “cases” in a case-control study, whereas not-at-fault drivers with the risk factor present are equivalent to “controls”.

3. RESULTS

3.1. Analyses

Crude relative risk ratios and statistical tests were first estimated for each potential risk factor, that is, not controlling for potential confounding factors. When this crude relative risk ratio (RR) equals 1, there is no accident risk associated with the health condition in question (i.e., there is no difference in risk between at-fault and not-at-fault drivers with the risk factor present). When RR > 1 there is an increased accident risk associated with the potential risk factor, and when RR < 1 there is a decreased accident risk.

The following procedure was used in order to estimate relative risk and confidence intervals:

(1) $$RR = \frac{a / n_a}{b / n_b}$$

(2) $$W = \frac{1}{1/n_a + 1/n_b + 1/a + 1/b}$$

(3) $$LogRisk = Ln\ \ RR\ \ *W$$

(4) $$95\ \%\ CI = Exp((LogRisk / W) \pm 1{,}96 * 1/\sqrt{W}$$

a = number of at-fault drivers with risk factor present

n_a = number of at-fault drivers

b = number of not-at-fault drivers with risk factor present

n_b = number of not-at-fault drivers

W = statistical weight
LogRisk = log transformation of estimate of risk

Second, all health condition variables were entered in a logistic regression together with various background variables. Thus, in this analysis, risk estimates were estimated when controlling for potential confounding background variables, as well as all other health conditions. In line with the quasi-induced exposure method, the dependent variable was culpability of accident (at-fault/not-at-fault).

3.2. Diseases

The percentage and frequencies of at-fault and not-at-fault drivers who suffered from diseases at the time of the car-crash are presented in the far right in table 1, along with corresponding crude relative risk ratios and 95 % confidence intervals. As for cardiac infarction and stroke, respondents were to indicate if they had *ever* experienced this (i.e., not *at* the time of the car-crash). Of all diseases, the only one that was significantly associated with increased accident risk was a history of brain stroke (75 % increased risk). Moreover, history of brain stroke is also the only disease that is associated with increased accident risk when controlling for potential confounding factors (OR=2.61, $p<0.05$) (odds ratios and corresponding p-values from the logistic regression analysis are presented in the far left of table 1 and 2). It is worth noting the rather small frequencies of respondents reporting that they suffered from some of the listed diseases at the time of the accident. With small frequencies, confidence intervals tend to be large, indicating that the "true" value of the relative risk ratio may be both very small and very large (i.e., the 95 % CI for RR of epilepsy indicates that the "true value" lays somewhere between 0.85 and 12.77).

Table 1. Logistic regression with "at-fault/not-at-fault" as dependent variable, percentage of drivers with risk factor (frequencies in parenthesis), and relative risks with 95 % confidence intervals. N=4703 (the table continues on next page)

			Percentage of drivers with risk factor*			
Variables	**Exp (B)**	**p**	**At fault n=1785**	**Not-at-fault n=2522**	**RR**	**95 % CI**
Background variables						
Sex (1=women, 2=men)	1.00	0.95				
Age	**1.02**	**0.02**				
Education	1.16	0.28				
Years with driver's license	**0.98**	**0.01**				
Familiarity with the road section in question	**0.39**	**0.00**				

Exposure (annual km)	1.00	0.95				
Diseases[3]						
Diabetes I	0.88	0.76	0.61 (11)	0.67 (17)	0.91	0.43-1.96
Diabetes II	0.94	0.82	2.24 (40)	2.02 (51)	1.11	0.73-1.68
Epilepsy	2.76	0.15	0.39 (7)	0.12 (3)	3.30	0.85-12.77
Parkinson	0.72	0.74	0.11 (2)	0.12 (3)	0.94	0.16-5.64
MS	0.41	0.27	0.11 (2)	0.36 (9)	0.31	0.07-1.45
Elevated blood pressure	0.99	0.93	9.30 (166)	9.00 (227)	1.03	0.84-1.27
Sleep-apnea	0.89	0.77	0.78 (14)	0.71 (18)	1.10	0.55-2.22
Auricular fibrillation	1.01	0.98	1.90 (34)	1.70 (43)	1.12	0.71-1.76
Arthritis	1.44	0.31	1.06 (19)	0.83 (21)	1.28	0.69-2.38
Ankylosis	0.52	0.26	0.33 (6)	0.48 (12)	0.71	0.09-5.43
ME (Myalgic encephalomyelitis)	2.02	0.35	0.33 (6)	0.12 (3)	2.83	0.71-11.31
Fibromyalgia	1.04	0.91	1.01 (18)	0.91 (23)	1.11	0.58-2.11
Other muscle or arthritic plagues/pains	1.22	0.42	2.69 (48)	1.86 (47)	1.44	0.96-2.17
Migraine	0.88	0.50	2.91 (52)	3.17 (80)	0.92	0.64-1.31
Angina pectoris	1.01	0.97	0.90 (16)	0.83 (21)	1.08	0.56-2.07
Asthma	0.94	0.61	10.36 (185)	10.82 (273)	0.96	0.79-1.17
Eczema	1.14	0.48	3.81 (68)	3.33 (84)	1.14	0.83-1.58
History of cardiac infarction	0.76	0.33	2.02 (36)	2.22 (56)	0.91	0.59-1.39
History of brain stroke	**2.61**	**0.02**	1.34 (24)	0.67 (17)	**1.99**	**1.07-3.72**

Significant relative risk ratios in bold
320 missing (logistic regression)

Table 2. Logistic regression with "at-fault/not-at-fault" as dependent variable, percentage of drivers with risk factor (frequencies in parenthesis), and relative risks with 95 % confidence intervals (extension of table 2). N=4703

			Percentage of drivers with risk factor			
Health plagues	**Exp (B)**	**p**	**At fault n=1785**	**Not-at-fault n=2522**	**RR**	**95 % CI**
Sleep onset insomnia	1.06	0.75	4.40 (78)	3.13 (79)	**1.40**	**1.01-1.92**
Waking up too early	0.96	0.82	5.94 (106)	4.96 (125)	1.20	0.92-1.56
General tiredness	**1.81**	**0.00**	11.1 (198)	6.30 (159)	**1.76**	**1.42-2.19**
Anxiety	0.57	0.19	0.78 (14)	0.67 (17)	1.16	0.57-2.37
Mild depression	1.57	0.22	1.57 (28)	0.75 (19)	**2.08**	**1.16-3.74**
Visual impairments						
Use glasses	1.11	0.32	46(823)	42 (1056)	1.10	0.99-1.23
Long-sighted	1.17	0.12	20 (350)	17 (437	1.13	0.97-1.32
Myopia	1.07	0.54	29 (511)	27 (672)	1.07	0.94-1.22
Astigmatism	0.89	0.18	19 (346)	19 (477)	1.02	0.88-1.19
Reduced visual field	0.75	0.55	0.56 (10)	0.40 (10)	1.41	0.59-3.40
Strong visual impairment on one eye	**2.42**	**0.00**	2.30 (41)	0.95 (24)	**2.41**	**1.45-4.01**
Reduced movability	1.25	0.20	4.82 (81)	3.69 (93)	1.31	0.97-1.76

[3] Diseases with and without medical treatment are included in the analyses.

Reduced hearing on one ear	0.95	0.72	5.60 (100)	6.07 (153)	0.92	0.71-1.20
Reduced hearing on both ears	1.21	0.21	6.61 (118)	5.47 (138)	1.21	0.94-1.56
Strong hearing impairment on one ear	1.85	0.13	1.18 (21)	0.56 (14)	**2.12**	**1.07-4.18**
Strong hearing impairment on both ears	2.61	0.14	0.62 (11)	0.16 (4)	**3.89**	**1.24-12.22**
Medication use						
Pain killers	0.73	0.21	5.04 (90)	4.36 (110)	1.16	0.87-1.54
Antidepressants	1.76	0.06	4.48 (80)	3.29 (83)	**1.36**	**1.00-1.86**
Anxiety reducing medicine	0.68	0.67	2.91 (52)	2.50 (63)	1.17	0.80-1.69
Muscle relaxing medicine	1.51	0.4	3.14 (56)	2.46 (62)	1.28	0.88-1.84
Sedatives	1.22	0.74	3.47 (62)	2.74 (69)	1.27	0.90-1.80
Allergy medicines	0.73	0.10	7.45 (133)	7.45 (188)	1.00	0.79-1.26

320 missing (logistic regression)

Significant relative risk ratios in bold

As this table is an extension of table 1, all background variables and diseases are controlled for in the logistic regression parameters presented here

3.3. Health impairments and medication use

Three general health plagues are significantly associated with increased accident risk when relative risk ratios are estimated for each health impairment; “sleep onset insomnia”, “general tiredness”, and “depression” (40, 76 and 108 % increased risk respectively). Of these, only “general tiredness” remains a significant predictor of accident risk when controlling for all other health conditions and background factor (OR=1.81, p<0.001). This was also true for “strong visual impairment on one eye”, with an increased risk of 41 percent when estimated separately, and an odds ratio of 2.42 (p<0.001) when controlling for confounding factors. As for hearing impairments, both “strong impairment” on one and two ears were significant risk factors when estimated separately, but turned insignificant when confounding factors where controlled for. Use of anti-depressants was barely significant when estimated separately (RR=1.36, CI=1.00-1.86), and tipped just below the significance level of 5 % in the logistic regression analysis (OR=1.76, p=0.06). Bivariate correlation analyses showed that use of anti-depressants correlated significantly with all health plagues as well as sex and use of anxiety reducing medicines, which may explain the non-significant odds ratio when controlling for confounding factors.

Finally, the logistic regression analysis showed that the following background variables were associated with increased accident risk: age (OR=1.02, p<0.05), years with driver’s license (OR=0.98, p=0.01) and familiarity with the road section (OR=0.39, p<0.001). Even though significant, the first two variables’ odds ratios are close to 1, indicating that there are only very small differences in risk. As for the variable “familiarity with the road”, however, there is a decreased risk of 61 percent, indicating that drivers who are very familiar with a road section are at smaller risk than drivers who is not familiar.

4. DISCUSSION

The main aim of this study was to investigate accident risk connected to various health conditions. When controlling for confounding factors, only three health conditions were associated with increased accident risk – a history of brain stroke, being plagued by general tiredness, and strong visual impairment on one eye.

Respondents were asked if they, at the time of the accident, suffered from one or more of seventeen chronic diseases as diagnosed by medical doctor. In addition, they were asked if they had experienced cardiac infarction or brain stroke. The results showed that none of the chronic diseases were associated with increased accident risk. Of the seventeen diseases, several have been identified as risk factors previously, among them diabetes (Sagberg 2006), Parkinson's diseases (Klimkeit et al. 2009), hypertension (Hours et al. 2008) and epilepsy (Charlton et al. 2004). One explanation of the results in this study, has to do with the low number of observations of the diseases – that is, there are only very few of the respondents who actually suffered from these diseases at the time of the accident. With few observations, randomness in the numbers will most likely have a large impact on the results, and "true tendencies" and significant results are harder to obtain.

Another point worth noting in this regard is the reason *why* there are so few with some of these diseases in this sample. This may have to do with the fact that the sample consists of drivers only. Thus, people who suffer from some of these diseases may renounce from driving simply because they are not allowed or don't feel safe when driving. This can be exemplified by for instance epilepsy; in Norway, people who have experienced an epileptic attack the last 12 months are not allowed to drive as laid down by law. In turn then, the respondents reporting to suffer from epilepsy in this study have probably not experienced an attack the last 12 months. Therefore, it is capital not to interpret the results in the present study that for instance experiencing an epileptic attack is not associated with accident risk. Rather, the interpretation should be that people who suffer from epilepsy, but who have not been bothered by attacks the last year, are not at increased accident risk. The same reasoning may apply to for instance hypoglycemia attacks experienced by patients suffering from diabetes. This argument calls for studies discerning strictly between the risk associate with sudden illnesses while driving (for instance stroke) and the risk associated with chronic diseases and functional impairments connected to such diseases (for instance multiple sclerosis). Evidence for increased risk have been found for both sudden and chronic illnesses (Lam & Lam 2005; McGwin, Jr. et al. 2000).

Having experienced a stroke was in this study associated with a significantly increased accident risk, indicated by both the crude relative risk estimate and the adjusted odds ratio. Charlton et al. (2004) report that the evidence of crash risk associated with stroke is inconclusive, i.e., "highly equivocal or no evidence". Nevertheless, there are previous indices that drivers having experienced a brain stroke are at increased risk (McGwin, Jr. et al. 2000; Sagberg 2006). Increased accident risk of drivers who have experienced a stroke may be associated to a) the increased risk of experiencing a new stroke after a minor stroke (Coull et al. 2004) which increases risk of traffic accidents during a new stroke while driving and b) cognitive and visual impairments which will affect driving behavior in general (Ponsford et al. 2008). With regard to cognitive and visual impairments, there is a line of research on the sensitivity and specificity of neuropsychological tests to identify patients who are not fit for driving after a stroke (Ponsford et al. 2008).

As for the self-reported health impairments investigated in this study, sleep-related plagues, mild depression, strong visual impairments on one eye, and hearing impairments were associated with increased accident risk when measured by crude relative risk estimates. However, only general tiredness and strong visual impairment remained significant accident risk predictors when controlling for confounding variables. Whereas both sleep-related health conditions and visual impairments have been found to affect accident risk in various studies (Connor et al. 2002; Sagberg 2006; Vaa 2003), the results are more inconclusive with regard to psychological distress. In the present study, mild depression was identified as a risk factor when measured by the crude relative risk ratio, however not when controlling for all other diseases and background factors. As mild depression often is accompanied by general tiredness, potential confounding between general tiredness and depression was tested. Mild depression was a significant predictor when entered together with age, sex, education and exposure in a logistic regression analysis. However, when entering general tiredness in this analysis, the odds ratio of mild depression turned insignificant, indicating that the two health condition variables share variance.

Finally, the present study confirms previous evidence that sleep-related problems and visual impairments are risk factors in traffic. Specifically, general tiredness and strong visual impairment on one eye are found to increase accident risk in the present study.

4.1 Implications and further research

Whereas knowledge gained from research on diseases and accident risk can be used to decide specific health requirements for holding a driver's license, such knowledge can also be used in a more general sense to inform medical doctors and the population of drivers. Medical doctors should for instance inform patients who complain about frequent tiredness about the increased risk associated with such health condition. As for the increased accident risk found for stroke, this should encourage further development of neuropsychological tests that can identify potential "at-risk-drivers".

Further research taking into consideration the limitations discussed in the present paper should be conducted in order to generate new and valuable knowledge in the field. This is particularly essential with regard to the investigation of chronic diseases, in which various limitations are present in this study. Better and more valid results would be obtained by the following improvements: a) in order to obtain more observations (i.e., more people with the disease), case-control studies in which cases are drivers diagnosed with the disease should be conducted, b) using objective estimates of diseases instead of self-report measures (e.g., medical records), while also c) controlling for confounding factors. As for further investigation of general health impairments, tested and validated measures should be used (e.g. Becks Depression Inventory, Epworth sleepiness scale, Subjective Health Complaint Inventory etc.)

On a more general note, research on accident risk associated with diseases and health impairments are important in order to inform the authorities who decide what health requirements need to be met in order to hold a driver's licence. However, it is important to keep in mind that knowledge generated from research on health conditions and accident risk need to be weighed against mobility needs for specific groups of people, e.g., elderly and people with specific chronic diseases and accompanied functional impairments (Charlton et al. 2004). Thus, a framework as proposed by Charlton et al. (2004) in which risk factors are investigated in relation to functional impairments and potential effective treatments, should be guiding the future research. In this way, a sound weighing of safety and mobility can be obtained.

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