

Summary:

ADHD and road accident risk

The present study reports results from a meta-analysis of 13 studies and comprise 27 results on relative risks of accidents of drivers with ADHD. The overall relative risk of accidents is estimated to 1.48 (1.26; 1.74) without control for exposure (mileage), to 1.30 (1.08; 1.57) when controlling for exposure, and to 1.24 (1.13; 1.35) when controlling for publication bias. These estimates are considerably lower than previous relative risk estimates, some as high 3-4 times higher than controls. It is hypothesized that comorbid states as **Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD) might contribute more to the number of accidents than ADHD alone.**

ADHD is a cerebral dysfunction which involves concentration problems and impulse control in about one half of adults who were diagnosed as a child. The abbreviation ADHD means Attention Deficit Hyperactivity Disorder, but this diagnosis has had many predecessors. In the 1970ies there was a huge increase in the research on hyperactivity among children. A group lead by the neuropsychologist Virginia Douglas at the American McGill-University, had a large impact on the understanding of hyperactivity and attention deficit. Douglas' main idea was that the hyperactivity was not the main problem, but rather a consequence of attention problems and impulsivity. The hypothesis then was that a deficit in attention leads to a state of hyperactivity. This understanding had a major impact when the DSM-diagnoses were revised in 1980 and the diagnosis was now stated as "Attention deficit disorder with or without hyperactivity". The DSM was again revised in 1987 (DSM-III-R) and the term that was established then was "Attention deficit hyperactivity disorder" (ADHD). A list of 14 symptoms of hyperactivity, impulsivity and concentration problems was agreed and a minimum of 8 symptoms had to be met if a diagnosis of ADHD should be set. In the most recent revision of DSM (DSM-IV in 1987) the notion of "attention deficit/hyperactivity disorder" (ADHD) was introduced and the group was divided in three sub-groups: Those predominantly hyperactive, those predominantly with attention problems, and those who had a combination of the two.

Previous studies on drivers with ADHD have indicated that ADHD-drivers had more accidents, more risky behaviours, traffic violations, and that they may have a higher risk of accidents compared to drivers without ADHD. It has been questioned, however, whether the basis for drawing such conclusions has been satisfactory. One problem has been that study samples have been small, another has been lack of controlling accident counts for exposure, even when mileage has been reported.

The purpose of the present project has been to study if drivers with ADHD have higher accident risk than drivers without ADHD, and these research questions are central:

1. Do drivers with ADHD have higher accident risk than driver without ADHD?
2. Do ADHD-drivers commit more traffic violations than drivers without ADHD?
3. Are there differences between subgroups in the population of ADHD-drivers regarding accident risk?

The present report comprise the following main areas:

- Evaluation of empirical studies on the risk of accidents
- Evaluation of literature reviews
- Simulation studies and other observational studies
- ADHD and effect of medication on driving outcome
- Evaluation of the quality of studies included in the meta-analysis
- Meta-analysis of studies that report accident counts for ADHD-drivers and controls
- A Norwegian study and risk estimation of drivers with ADHD
- A critical discussion on how accident risk of ADHD-drivers is understood among Norwegian experts on ADHD
- Discussion of risk estimates from meta-analysis
- Conclusions

Empirical studies of accident risk

Even if the literature apparently concludes unambiguously that drivers with ADHD have higher accident risk than the rest of the population, it must be underlined that the empirical basis for drawing conclusions is not very comprehensive. A majority of the studies only comprise young drivers which imply that the accident risk is overestimated with regard to the all drivers in the ADHD-population.

Another weakness is that the definition of ADHD has not been stable across the time-period which is comprised by the studies, several of the research projects are longitudinal projects where young adults, who were diagnosed as children, are studied. However, the diagnosis may have been revised, especially by DSM-IV, where the diagnosis was enlarged to include more in the inattentive part of ADHD, which also would comprise more of the girls. Some of the studies do not report ADHD, but related conditions.

A majority of the studies have small numbers of subjects often sampled from ADHD-clinics and through ads in newspaper or magazines that gather referrals to medical clinics where sampling biases may be present. There is also a strong tendency in most studies not to control for other factors that may affect the outcome, as exposure (mileage), age, IQ, education and socio-economical status.

Three of the studies report a significant association between ADHD and accidents. One study reports a significant association for self-reported accidents, but no association with official accident statistics. Even if there is a significant association between ADHD-diagnosis and an elevated accident risk, one cannot conclude from correlation to causality. Several of the studies report that drivers with ADHD also

have other demographical differences, as lower IQ, lower socio-economic status and less reading skills. Such differences may potentially explain an elevated accident risk. Further, many of the drivers with an ADHD-diagnosis, also have other, comorbid diagnoses, especially *conduct disorder* (CD) and *oppositional defiant disorder* (ODD). One study reports that 20-40% of the ADHD-drivers also had conduct disorder, another study reports 42.7-93.0 also had conduct disorder and/or oppositional defiant disorder.

Observation of behavior/Simulator studies

Even if ADHD-drivers often score worse in simulator driving tests than controls, the differences have been minor, - and in some situations non-existent. Taking the limitations of simulator studies into account, the material does not provide sufficient basis to draw conclusions about ADHD and driving skills. Self-evaluation and evaluations done by other parties will inevitably remain an imprecise measure. There is no basis for stating that ADHD-drivers have less knowledge or increased risk compared to controls.

Medical treatment

Studies on medical treatment of ADHD-patients' driving skills is to some extent unsatisfactory. Most studies comprise a limited number of subjects, they are often teenagers, which make generalization difficult. The only study without these limitations does not report any significant improvement compared to placebo. However, some outcomes may indicate that medication may benefit at least some groups of ADHD. No negative outcomes have been reported.

Meta-analysis

The meta-analysis is based on 13 studies which comprise a total of 27 results. The present reports present an overview of year of publication, country, research design, confounding factors (if stated), exposure (if present), relative risk of accident (RR), confidence interval and weight (weight is a variable that expresses the number of accidents each of the results is based on).

The quality of studies comprised by the meta-analysis varies. In an evaluation of quality most of the studies are considered as inferior, but all studies which comprise accident data are nevertheless included. Even if the data and number of results is limited, the meta-analysis nevertheless provides opportunities to estimate RR for some sub-groups in the material (a limit of 5 results is set as a minimum for estimating RRs). RR is estimated for the following groups and sub-groups:

- Relative risk – all studies (number of results: 27)
- Relative risk in a sample comprising a high amount of comorbidity (number of results: 5)
- Relative risk of property-damage-only accidents (number of results: 9)
- Relative risk of personal injury accident (number of results: 11)
- Relative risk for drivers on medical treatment of ADHD (number of results: 5)

There are options of estimating RR for sub-groups of men and women, but the numbers of results are 4 and 3, respectively, which is considered as too low to justify estimation of RRs for men and women separately. The presentation of RR-estimates is done only by a random-effect model, even in instances where data is not heterogenous.

New estimates of accident risk

- Considering the complete sample of results, the relative risk (RR) is estimated to 1.48. This number means that drivers with ADHD have an accident risk which is 48% higher than drivers without ADHD. The estimate is statistically significant on the level of $\alpha = 0.05$. The confidence interval is (1.26; 1.74).
- The best indicator of exposure is mileage. It is especially important in the present context to correct an estimate of relative risk of accident by mileage because ADHD-drivers in general seem to drive more than controls. Mileage is stated for about half of the results and the RR within this sub-group where mileage is given, the RR is 1.30 (1.08;1.57). i.e. considerably lower than for the whole group.
- It is a clear tendency of publication bias represented by the studies included in the present meta-analysis. After correcting for publication bias the RR is 1.24 (1.13; 1.35).
- Both in Norway and internationally an understanding that ADHD-drivers have an accident risk of 3-4 times higher than average has prevailed. One of the most important conclusions from the present review is then that the accident risk level of ADHD-drivers is considerably lower. Relative risks of other diseases and conditions that are known and which can be compared to ADHD vary between 1.09 for visual impairment and 3.71 for sleep apnea. The RRs which are estimated in the present context are comparable those of heart diseases (1.24) and diabetes mellitus (1.56).
- The material provides a basis for estimating RR of property-damage-only and personal injury accidents, which are 1.19 (0.96; 1.48) and 1.90 (1.48; 2.43) respectively. It then seems to be a higher probability that the outcome of an accident would be a personal injury accident rather than a property-damage-only accident. i.e. the level of injury could be higher when drivers with ADHD are involved, compared to controls. ADHD-drivers have more speeding tickets, which indicate that some ADHD-drivers drive faster – or longer - than controls. Some studies comprise cases with comorbidity, but it is not possible to assess the partial contributions from ADHD, ODD and CD alone. These estimates must, hence, be interpreted with caution.
- In studies comprising high amounts of comorbidity represented by Oppositional Defiant Disorder (ODD) and/or Conduct Disorder (CD), RR is estimated to 1.79 (1.27; 2.51), i.e. 21% higher than the total sample of ADHD-drivers. The interpretation is, however, complex and involves hypotheses on how ADHD and other specific psychiatric diagnoses might contribute to an elevated risk level. A tendency which is seen in some of the studies is that some drivers do have more than one accident, and it is a question if this tendency might be associated with the comorbidity of ODD and CD.

- In 2002/2003 a survey was conducted in Norway among members of the Norwegian ADHD Society. 582 questionnaires were distributed and 289 members responded giving a response rate of 49.6. Of these 172 had a driving license. 29 drivers were involved in 37 accidents in the preceding 3 years, 4 with personal injury. Based on information about total mileage, an accident risk of 0.47 accidents per million km. Compared to the average of all Norwegian drivers, which was 0.36 in the period 2005-2007, it is somewhat higher. Considering all accidents in this dataset, i.e. including property-damage-only accidents, the accident risk was 4.36 accidents per million km. This risk is then somewhat lower compared to two other contemporary Norwegian projects involving drivers where accident risks were calculated to 6.24 (all Norwegian drivers) and 10.1 (sample of impaired drivers) accidents per million km.

Tests on attention functions is found only in two studies. These test results do not support a conclusion that ADHD-drivers should have any significant attention deficit in a context of driving compared to controls.

Future research should concentrate on a distinction between "ADHD only" and "ADHD with ODD and/or CD" as it is argued and hypothesized that the comorbid states of ODD and CD might contribute more to an elevated accident risk than ADHD alone.