

Developing limits for driving under cannabis

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ABSTRACT

Objective Development of a rational and enforceable basis for controlling the impact of cannabis use on traffic safety. **Methods** An international working group of experts on issues related to drug use and traffic safety evaluated evidence from experimental and epidemiological research and discussed potential approaches to developing *per se* limits for cannabis. **Results** In analogy to alcohol, finite (non-zero) *per se* limits for delta-9-tetrahydrocannabinol (THC) in blood appear to be the most effective approach to separating drivers who are impaired by cannabis use from those who are no longer under the influence. Limited epidemiological studies indicate that serum concentrations of THC below 10 ng/ml are not associated with an elevated accident risk. A comparison of meta-analyses of experimental studies on the impairment of driving-relevant skills by alcohol or cannabis suggests that a THC concentration in the serum of 7–10 ng/ml is correlated with an impairment comparable to that caused by a blood alcohol concentration (BAC) of 0.05%. Thus, a suitable numerical limit for THC in serum may fall in that range. **Conclusions** This analysis offers an empirical basis for a *per se* limit for THC that allows identification of drivers impaired by cannabis. The limited epidemiological data render this limit preliminary.

Keywords Accident risk, adverse effect, cannabis, driving, drug, DUI, DUID, limit, marijuana, Psychomotor impairment.

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INTRODUCTION

The rising prevalence of driving under the influence of illegal and medicinal drugs (DUID) and its potential impact on traffic safety have raised awareness among media, scientists and policy makers in many countries and prompted calls for more effective control. Driving under the influence of cannabis (DUIC) is of particular concern, because the recreational use of cannabis products, i.e. marijuana and hashish, is often second only to alcohol. This highlights the need for effective legal control of the potential risks posed by DUIC.

Current approaches to assessment and control of DUIC

Current DUID laws use one of three basic approaches to determine whether a driver involved in an accident or stopped at a roadside checkpoint, is impaired or under the influence of a particular drug. One is the traditional

impairment or effect-based approach; the others are two versions of the '*per se*' approach. The *per se* approach uses, as in the case of alcohol, a science-based finite limit or employs a zero limit for the tolerable concentration of a drug or its metabolites in a driver's blood or other body fluids. In either case, exceedance of this limit is deemed automatically to prove (legal) impairment.

In theory, the impairment approach best meets the objectives of DUID laws. It observes and assesses the fitness of drivers and potentially penalizes those who are actually impaired. Impairment may arise from several, often-synergistic factors, including fatigue and the consumption of multiple drugs. The main limitation of the impairment approach is the lack of standardized methods for measuring and judging the impairment caused by drug consumption. Standardized sobriety tests are sensitive and reliable when used by trained officers to detect blood alcohol contents of more than 0.1%. These tests

case-control or culpability approach, epidemiology assesses the actual risk of a drugged driver causing an accident, relative to that of a sober person driving under similar road conditions. That relative risk is expressed as odds ratio (OR). An OR greater than 1 corresponds to a higher accident risk for the 'case group', i.e. drivers under the influence of a drug, compared to the 'control group'.

Epidemiological studies measure the effect of drug use on driving performance and accident risk under 'real life' conditions and are thus suited to correlate the concentrations of a drug use indicator to an actual risk. For alcohol, scientists have developed, based on the results of numerous epidemiological studies, hazard curves that assign each alcohol concentration to a certain accident risk. As with all epidemiological findings, the validity of each study depends critically on the number of cases included. Driving under the influence of alcohol is a widespread phenomenon and screening of drivers for alcohol using breath analysers is non-invasive. This allowed researchers to collect, for a given time of day, region, road condition and for each BAC class enough cases to yield statistically significant ORs.

Fortunately for traffic safety but unfortunately for epidemiological research DUI is far less common. Furthermore, meaningful testing for cannabis use requires the collection of blood samples, a procedure that in most countries cannot be used unless a driver is suspected of DUI. Thus, epidemiological studies on DUI do not usually have sufficient THC positive cases to calculate reliably concentration-dependent ORs.

Detailed overviews of epidemiological studies on DUI have been provided by Bates & Blakely [8], Cheshier & Longo [9], Oğden & Moskowitz [10] and Ramaekers *et al.* [11]. Drummer *et al.* conducted one of only few epidemiological studies that correlated THC concentrations in blood and accident risk and met quality criteria not met by other such studies [12]. The study used accident data from drivers fatally injured in accidents in Australia and found that THC concentrations in whole blood in the range of 0–5 ng/ml were associated with an OR of 0.7 and concentrations between 5 and 100 ng/ml with an OR of 6.6 (95% CI: 1.5–28). Note that both ORs represent an average for the entire respective range of THC concentrations, so the average OR for a driver with a THC concentration in blood of anywhere between 5 and 100 ng/ml is 6.6. Because OR and blood THC concentration are probably correlated by a linear or even exponential function, the point risk at 5 ng/ml THC in whole blood is considerably much lower than 6.6.

To differentiate more clearly the correlation between OR and THC concentration in the 0–20 ng/ml range G. Berghaus and G. Sticht (personal communication) developed the data by Drummer *et al.* into a polynomial function. The results in Fig. 1 show that THC concentrations

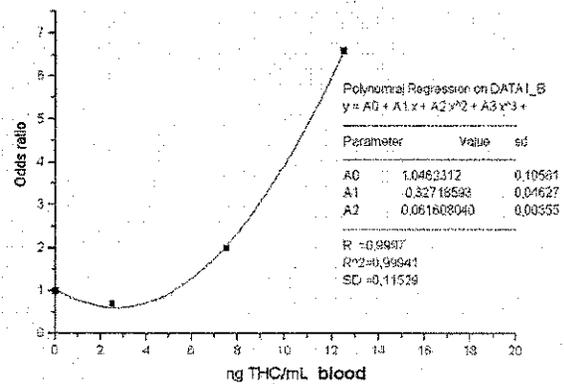


Figure 1 Correlation between delta-9-tetrahydrocannabinol (THC) concentration in whole blood and accident risk (odds ratio) calculated with the data of the study by Drummer *et al.* [12]

in blood are not associated with an elevated risk (OR > 1) until they exceed about 6 ng/ml.

Comparison of these cannabis-induced risks to those associated with driving under the influence of alcohol yields a first approximation to a numerical *per se* limit for DUI. A BAC of 0.05% alcohol is associated with an OR of about 1.5–2 [13–15]. According to Fig. 1, that range corresponds to a THC concentration in whole blood of about 6–8 ng/ml, equivalent to a THC concentration in serum of about 12–16 ng/ml. The latter assumes a typical conversion factor of 2 between THC concentrations measured in blood versus serum.

As the study by Drummer *et al.* was based on only 58 cases whose blood samples contained only THC and no other indicators of drugs, the above considerations do not yield a statistically acceptable basis for an enforceable *per se* limit. The latter would require epidemiological data from a far larger number of cases.

A more recent epidemiological study, conducted in France by Laumon *et al.* [15], evaluated a much larger sample of THC-positive drivers ($n = 681$) who were involved in fatal accidents. Of them, 285 also tested positive for alcohol with a BAC > 0.05%. The adjusted OR (adjustment for alcohol, driver's age, type of vehicle and time of crash) for all THC positive cases was 1.78 (95% CI: 1.40–2.25), with the OR of cases with THC concentrations in blood of less than 1 ng/ml being 1.57 (95% CI: 0.84–2.95) and the OR of the subgroup with the highest THC concentrations (≥ 5 ng/ml whole blood) being only slightly higher (OR = 2.12, 95% CI: 1.32–3.38). The overall OR of 1.78 reported by Laumon *et al.* [15] is similar to that found by Drummer *et al.* [12] (OR = 2.7, 95% CI: 1.02–7.0), and in line with other studies that found only a small overall increase of accident risk in THC positive drivers, e.g. Terhune [16] (OR = 2.1), or even no increase, e.g. Longo *et al.* [17] (OR = 0.9). However, the findings by Laumon *et al.* [15] contradict those from all

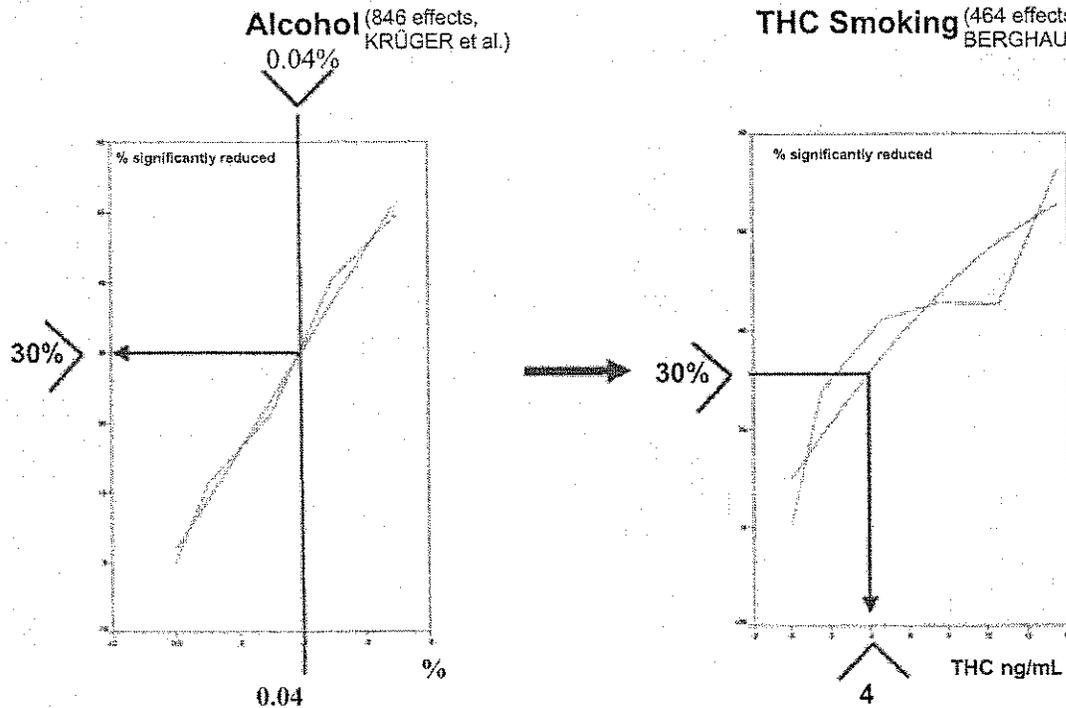


Figure 2 Comparison of survival functions for delta-9-tetrahydrocannabinol (THC) (in serum) and alcohol (in whole blood) and establishment of points of equal impairment. One curve represents the data really measured (unequal curve), the other curve represents the linear (blood alcohol concentration) or exponential (THC) smoothing

alcohol. A major shortcoming of this approach is its failure to consider whether the influence of alcohol and cannabis, respectively, promote different adaptive behaviors that may modify accident risk under actual road conditions [18]. Another limitation of this meta-analysis, as described below, is that it included test results for indicators with no clear link to driving performance, such as flicker fusion.

Within these limitations, a comparison of results from meta-analyses for alcohol and THC, respectively, then generates, for a given THC blood concentration, the corresponding BAC that causes the same level of impairment in test skills and for which accident risk is well established. For example, one may regard the THC concentration in blood at which the same percentage of all test results shows impairment as with a BAC of 0.05% as the THC concentration equivalent to that BAC.

The working groups of Krüger and of Berghaus conducted, in the 1990s, meta-analyses of suitable experimental studies on the effects of low doses of alcohol and cannabis [19,22,23]. Their work allowed a first systematic and quantitative comparison of the results of experimental research on the effects of THC and alcohol, respectively. For their meta-analysis of experimental studies on cannabis, Berghaus *et al.* first selected, out of more than 120 studies, those published in English or German and meeting the following minimum criteria:

testing of at least one driving-relevant skill, a minimum of five human participants per study, information given on THC dose and mode of administration; number, age and gender of subjects; time delay between consumption and testing; type of test performed (e.g. tracking, visual function), and the specific tasks (e.g. two-hand-coordination, flicker fusion). Test results had to be coded as 'significant improvement or impairment', at least at the 5% level or as 'no significant change' [19].

Studies in which THC had been taken together with other drugs or alcohol were excluded. Overall, 66 studies in which cannabis had been smoked and 21 with oral intake of cannabis were selected, including laboratory tests, driving simulator and on-road studies. Blood THC concentrations at the time of testing were estimated from the information on THC dose and other factors using the pharmacokinetic model by Sticht & Käferstein [21].

Figure 2 summarizes the key results from the two meta-analyses. For alcohol and smoked cannabis, respectively, each graph shows a set of two 'survival functions'. The respective curves give the percentage of results from all tests that showed significant impairment at a given BAC or THC concentration in serum. One curve represents the original data; the other curve shows the results of linear (BAC) or exponential (THC) smoothing. Comparison of the two graphs thus suggests that a BAC of 0.04% and a serum THC concentration of 4–5 ng/ml

Other modifying factors

Three other potentially modifying factors must be considered when setting legally binding numerical *per se* limits for THC. First, the epidemiological study by Drummer *et al.* suggests that THC concentrations indicate elevated accident risk at levels higher than indicated by experimental studies [12]. This may be due to the more pronounced adaptive behaviours (slowing down, reduced risk-taking) observed with cannabis-affected drivers in driving simulator and on-road studies, both of which represent more closely real-life conductions. In that case, comparison of experimental studies for alcohol and THC, respectively, would result in systematically lower *per se* limits for THC than derived from epidemiological studies.

Secondly, cannabis consumption produces measurable THC residues in blood long after smoking. At 10 hours after smoking residual THC concentrations in the serum of occasional or even frequent users have declined to typically less than 5 ng/ml. The suggested *per se* limit in the range of 7–10 ng/ml safely avoids misclassification of drivers presenting with THC residues from previous cannabis use. It would also spare drivers with low but measurable THC concentrations caused by passive exposure to cannabis smoke or by smoking or oral intake of low THC doses for medicinal purposes [26–31].

Finally, a legal *per se* limit for cannabis must consider that the concurrent use of alcohol and cannabis impairs driving skills more than each drug individually [32]. For drivers presenting with measurable THC concentrations and a BAC exceeding 0.03% or 0.05%, a lower *per se* limit for THC than proposed above may be appropriate.

Using current scientific evidence on cannabis-induced impairment of psychomotor skills and the related accident risk, this paper suggests a range of 7–10 ng/ml THC in the serum for an initial non-zero *per se* limit. It offers reasonably reliable separation of drivers whose driving is in fact impaired by cannabis from those who are not impaired. Inadequate evidence from epidemiological studies renders this limit preliminary and suggests the need for review and possibly revision in the future. Our findings also suggest that using a zero limit for legal determination of impairment by cannabis, which in practice corresponds to the limit of detection for THC in blood, would classify inaccurately many drivers as driving under the influence of, and being impaired by, the use of cannabis.

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