SALIVARY CORTISOL: A PREDICTOR OF CONVICTIONS FOR DRIVING UNDER THE INFLUENCE OF ALCOHOL?

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(Received 9 February 2005; first review notified 8 March 2005; in revised form 4 April 2005; accepted 6 April 2005; advance access publication 24 May 2005)

Abstract — Aims: To examine the relationship between salivary cortisol and frequency of past driving under the influence of alcohol (DUI) convictions. Methods: A total of 104 males with previous DUI convictions (from one to eight) and mean age of 44.7 years were assessed on measures characterizing repeat DUI offenders, including sociodemographic information, alcohol use behaviours, biological indices of the organic consequences of chronic abuse, negative consequences of excessive drinking, past DUI conviction history, impulse control, and antisocial behaviour tendencies. Saliva samples were taken approximately every 30 min over a 6 h period during an exhaustive multidimensional assessment protocol, and were then assayed to obtain cortisol responses. Results: Blunted cortisol response, typically observed in alcoholics and in high-risk non-alcoholics, was associated with increased number of past DUI convictions. This association was particularly pronounced in multiple DUI offenders, and was stronger than, and independent of, other measures of alcohol use severity and chronicity commonly used for DUI assessment. Conclusions: Cortisol response may be useful in understanding the mediators underlying repeat DUI offending and the frequent failure of intervention efforts in curbing DUI behaviour.

INTRODUCTION

Driving under the influence of alcohol (DUI) is a behaviour with important individual, social, and health consequences. In the US, traffic accidents are the leading cause of death for people aged 2–33 years, with alcohol being implicated in 41% of all fatal crashes (Hingson and Winter, 2003). These statistics are paralleled in other countries (Smart and Ogborne, 2000; Brinkmann et al., 2002). Approximately 33% of those convicted for DUI become repeat offenders (Brinkmann et al., 2002), and 35–40% of all fatally injured driving drivers had a prior conviction for DUI (Beirness, 1991). The persistence of DUI behaviour makes it the most dangerous, yet preventable, liability on the roads. Accordingly, the consensus among highway safety advocates and public health professionals is that an arrest for DUI is a singular opportunity to identify high-risk drivers and initiate remedial measures (National Highway Traffic Safety Administration and National Institute of Alcohol Abuse and Alcoholism, 1997).

Data on the prevalence of alcohol use disorder (AUD) among individuals who drink and drive suggest that it is significant but that measurement can be imprecise. A recent review indicates that prevalence rates range between 25 and 50% (Korzec et al., 2001), depending on sampling and the criteria used. Assessment involving interviews and questionnaires is a customary procedure following a DUI conviction to establish risk for re-offending, fitness for re-licensing, and appropriate remedial strategies. However, the current capacity to accurately identify at-risk individuals, beyond a reliance on AUD diagnosis and past history of DUI convictions, is also limited (Anderson et al., 2000; Voas, 2001). This reflects both the limitations in our understanding of the complex web of factors that contribute to DUI recidivism, as well as the shortcomings in assessment and sampling methodologies.

With respect to the former, the risk for repeat DUI has been associated with several individual characteristics other than an AUD. These include age, gender, driving behaviour, family history of alcoholism, personality characteristics such as antisocial tendencies and risk-taking, and impairment in executive (e.g. impulse control) and cognitive (e.g. memory) functioning (Macdonald and Mann, 1996; Lapham et al., 1997; Glass et al., 2000; Hingson and Winter, 2003). Moreover, there does not appear to be a simple association between punishments and sanctions and the likelihood of recidivism (Yu, 2000).

The effectiveness of assessment protocols is also problematic. The accuracy of self-reported drinking and driving behaviour by DUI offenders is uncertain, and a tendency to under-report has been observed in many contexts (Lapham et al., 2002). Biological measures have been shown to be useful for detecting harmful chronic drinking (Iffland, 1996), but do not address DUI risk directly (Ruud and Gjerde, 1992). Moreover, their sensitivity drops drastically in younger individuals and for less severe patterns of drinking (Korzec et al., 2001). These findings have led to the development of statistical algorithms using several different measures that can predict DUI recidivism significantly better than chance. However, they can be complicated and of insufficient validity for ready clinical utilization (C’dé Baca et al., 2001).

Finally, the representativeness of participants recruited in DUI studies is uncertain. Recruitment of DUI offenders usually occurs in specific contexts such as in DUI remedial programmes, which facilitates their selection by researchers. However, in the province of Quebec, as in other jurisdictions,
that they posit a relationship between cortisol and a complex 
abstinent (Errico et al., 1993; Bernardy et al., 1996; Lovallo et al., 2000). Increased secretion and blunted cortisol response to psychological stress has also been observed in non-alcoholic individuals at high-risk for developing alcoholism (i.e., sons of alcoholic parents or other family members) (Dai et al., 2002; Zimmermann et al., 2004). Finally, there are preliminary data that suggest that the degree of attenuation in cortisol responses to stress or alcohol cues is associated with higher probability of relapse 6 weeks following alcoholism treatment (Junghanns et al., 2003, 2005), suggestive of a biological component of treatment resistance.

Blunting of cortisol response to stress has been associated with other characteristics frequently related to, but also independent of, excessive drinking. For example, significant cognitive impairment, specifically in memory function, in alcoholics (Errico et al., 2002) as well as non-alcoholics (Kirschbaum et al., 1996) has been associated with high cortisol responding. Blunted cortisol response to serotonergic agonists, and an inverse relationship between measures of impulsive-aggression and serotonergic function, have been widely observed among adults with impulsive and aggressive behavioural traits or with impulsive personality disorders (Soloff et al., 2000). Overall, these findings are intriguing in that they posit a relationship between cortisol and a complex array of behaviours that have been linked with DUI recidivism. However, no study to date has yet directly explored cortisol response in relation to DUI recidivism.

This preliminary retrospective study probed the relationship between salivary cortisol and DUI conviction history in a sample of men convicted of one or more DUI offences. Participants were recruited from a larger study protocol that involved a number of potentially stressful or cognitively challenging tasks, including blood taking, probing interviews, and neuropsychological tasks. Salivary cortisol was assessed at ~30 min intervals during the 6 h assessment protocol. We hypothesized that a significant inverse relationship would be observed between cortisol response and previous number of DUI offences, consistent with the blunting of cortisol response in alcoholics and other high-risk samples. If this hypothesis was supported, additional analyses were planned. Correlational analyses would compare the relative strength of association between frequency of past DUI offences, cortisol response, and measures commonly used in the assessment of DUI offenders during the license reacquisition process. Finally, exploration of the associations between factors common to both cortisol response and DUI offending, such as excessive drinking, antisocial behaviour patterns, and impulsivity, would be undertaken to generate further hypotheses concerning the mediators between cortisol response and DUI.

METHODS

Participants
Study participants were recruited with the collaboration of the Société d’assurance automobile du Québec (SAAQ) (the Quebec Licensing Bureau). Eligible adults living within a 50 mile radius of Montreal were randomly selected from the SAAQ database and sent a description of the study and an invitation to participate. The identity of these individuals was not revealed to the study team. When interested individuals responded to this invitation by phone, a first selection for study eligibility was undertaken. Inclusion criteria were at least one conviction for DUI in the previous 5 years, and aged ≥18 years. Exclusion criteria included a positive breathalyser test and/or signs of intoxication, and being female. Women were excluded from this study for two main reasons: the limited number of convicted female drivers in the available sample, which reflects the significant over-representation of males in the DUI population, and our inability to control for important gender differences in HPA-axis activity related to menstrual cycles (Gianoulakis et al., 2003). A rendezvous was then made at a convenient day for the participants to come to the lab. Participants were informed that they would be compensated CAN $160.

Ethical considerations
The study’s recruitment procedure and Informed Consent provisions were approved by the Douglas Hospital Research Ethics Board.

Site
The study was conducted at the Addiction Research Program’s facilities located in the Douglas Hospital Research Center, a psychiatric care facility affiliated to the McGill University
Faculty of Medicine in Montreal, Canada. It has dedicated and secure waiting and interview rooms, and onsite capacity for blood, urine, and saliva preparation and assay.

**Instruments**

Age and other sociodemographic data were obtained using the Addiction Severity Index (McLellan *et al.*, 1985). Diagnosis of substance use was made using the structured, computer-assisted Composite International Diagnostic Interview (Kessler *et al.*, 2004), which facilitates diagnostic classification of AUDs based upon the Diagnostic and Statistical Manual of Mental Disorders. The Michigan Alcoholism Screening Test (MAST) and the Drug Abuse Screening Test (DAST) are brief self-administered questionnaires and yield a quantitative index of problem severity with established parametric qualities in this population (Mischke and Venneri, 1987; Lapham *et al.*, 1995; Conley, 2001). The Alcohol Use Disorders Identification Test (AUDIT) (Babor and Grant, 1994) is a clinical screening instrument with 10 items that yields an index of alcohol problem severity and related negative consequences. It has well-established parametric qualities in the general population (Reinert and Allen, 2002) and adequate proficiency in the DUI population (Lapham *et al.*, 1995; Conley, 2001). The Mortimer–Filkins Questionnaire (MFQ) is a frequently employed questionnaire contrived for detecting problem drinkers specifically among DUI offenders, and has been found to possess reasonable parametric characteristics (Mischke and Venneri, 1987). The Timeline Follow-Back presents patients with a calendar and asks them to recall instances of drinking or substance use on a daily basis over the past 90 days. This technique has been found to minimize inaccuracies in the reporting of quantity/frequency of substance use (Sobell *et al.*, 1996; Fals-Stewart *et al.*, 2000). The number of past DUI convictions and history of adherence to mandatory programmes for license re-acquisition was obtained through self-report, and corroborated, with participant consent, by the SAAQ administrative database. The Barratt Impulsivity Scale version 11 (Patton *et al.*, 1995; Barratt *et al.*, 1997) is a 30-item questionnaire that provides measures on three dimensions of impulsive behaviour, cognitive impulsivity, behavioural impulsivity, and planning. The Millon Clinical Multiaxial Inventory III (MCMI) (Millon, 1985; Piotrowski, 1997) contains 175 items that produce 28 scales. The MCMI is one of the most popular clinical instruments in use, and in its third revision, provides validated information regarding probable Axis I and Axis II disorders. The Antisocial and Alcohol Dependence Scores were extracted for consideration in this study.

**Measurement of cortisol response**

Salivary cortisol was sampled over time while participants completed a battery of tests during the 6 h experimental session for the larger study. The first sample was gathered after the participant had read and signed the Informed Consent form. Subsequent samples were gathered after blood taking, paper-and-pencil tests of substance use, psychosocial adjustment, and psychological distress in the morning (i.e. $T_1 - T_0$), and neurocognitive testing (e.g. Rey Complex Figure Test and Recognition Trial, Verbal Fluency Test, Wechsler Memory Test, Ruff 2 & 7 Selective Attention Test, Trail Making Test, Tower Test, Stroop Color–Word Interference Test, and Go/NoGo task) in the afternoon (i.e. $T_h - T_{11}$). Saliva was collected in the short intervals between tasks, with swabs being administered as close to 30 min intervals as possible. Thus, some variability in the timing of specific assessment procedures was unavoidable.

Saliva was collected using the Salivette sampling device (Sarstedt, St Laurent, Quebec, Canada). This is a non-invasive and stress-free technique. Participants simply chewed a swab for several seconds. Samples were refrigerated immediately until assayed. Cortisol in saliva represents the free fraction of cortisol in plasma (not bound to cortisol binding globulins) (Kirschbaum and Hellhammer, 1994). The content of cortisol in saliva was estimated using the AMERLEX Cortisol radioimmunoassay kit (catalogue number 8758401; Ortho-Clinical Diagnostics, Inc. Rochester, NY). Results are reported as μg cortisol/100 ml saliva. The sensitivity of this cortisol assay is 0.1 μg/100 ml. The intra-assay and inter-assay coefficients of variation were 4.3 and 7.7%, respectively.

Three cortisol measures were considered: (i) cortisol levels at baseline ($T_1$), (ii) total cortisol (i.e. area under the curve), and (iii) cortisol response. Cortisol response was operationalized as the aggregate of all positive change from one interval to the next over the entire 6 h assessment period; that is: If $(T_{x+1} - T_x) > 0$, then $\sum_{i=1}^{10} (T_{x+1} - T_x)$. Observations during lunch ($T_6 - T_9$) were not included in the calculation of cortisol response owing to predicable fluctuations immediately following meals (Gianoulakis *et al.*, 2005).

**Measurement of hepatic enzymes**

Gamma-glutamyl transferase (GGT), carbohydrate-deficient transferase, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and mean corpuscular volume (MCV) are recognized markers for excessive alcohol use (Schwan *et al.*, 2004) and were measured through blood immunoassay. Use of multiple measures increases their specificity (Allen and Litten, 2003), which is associated with a higher probability of alcoholic hepatitis, over and above markers considered alone. Blood samples were collected in plain Vacutainer® tubes. The blood sera were analysed on the same day using an automated clinical chemistry analyser at the St Mary’s Hospital Centre, Montreal, Canada. Normal values for MCV range from 80 to 100 fl, though prevalence studies of alcoholism in DUI samples using MCV have set the cut-off at >96 fl. Normal values of GGT are <40 IU/l, with prevalence of alcoholism in DUI samples being determined by GGT >50 IU/l. Both expressed as IU/l, the AST/ALT ratio is typically >1 in alcoholic liver disease and <1 in non-alcoholic liver disease (Korzeck *et al.*, 2001).

**Procedures**

Prospective participants arrived at the laboratory at 8.30 a.m., were provided the Ethics approved Informed Consent forms to read, discuss with the research assistant, and sign if acceptable. They were brought to the Douglas Hospital Clinical Investigations Unit for breathalyser and blood sampling under the supervision of medical personnel. They were then led to the interviewing room to continue the behavioural and psychosocial assessment portion of the main
study protocol. From the time of signing the Informed Consent form, participants were provided chewable cotton swabs to capture saliva samples at 30 min intervals.

RESULTS

A sample of 112 participants was recruited for this facet of the larger study protocol. Saliva data from eight participants were rejected owing to either inadequate amounts of fluid for assay or ruined samples. Table 1 summarizes the characteristics of the final sample of 104 participants. The distribution of DUI conviction frequency was as follows: 41.1% of the sample had one conviction, 31.3% had two convictions, and 27.6% had three or more convictions (four participants). Moreover, 27.9% of the sample had failed to comply with sanctions and remedial measures in the past, and 53.7% had not re-obtained a permit to drive. While >20% were assessed as having a current AUD, it was also found that 25.2% of the entire sample possessed one or more biological indices (i.e. GGT, MCV, or AST/ALT >1) consistent with a diagnosis of alcoholism in DUI samples (Korzec et al., 2001).

Figure 1 depicts the average cortisol response profile at all 11 sampling intervals, and the schedule of experimental tasks participants performed over the testing period. Initial analyses conducted on frequency of past DUI offences vs either baseline ($T_1$) cortisol levels or total cortisol (i.e. area under the curve) did not reveal systematic relationships. Initial descriptive analyses of aggregate raw cortisol response exposed a

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Fig. 1. Mean salivary cortisol ($\mu g/100$ ml) and standard error from $T_1$ to $T_{11}$, taken at ~30 min intervals during exposure to a comprehensive assessment battery.
multiple DUI offenders (i.e. heteroscedasticity). While not invalidating analysis of association, this variance can weaken it. Thus, two runs of correlational analyses were conducted to explore associations between the number of DUI convictions and cortisol response, measures of alcohol commonly employed in DUI assessment protocols, the three Barratt impulsivity measures, and the Millon alcohol dependence and antisocial scales: first with the entire sample, then only with multiple DUI offenders (i.e. heteroscedasticity). While not correcting this anomaly (Tabachnick and Fidell, 2000).

Figure 2 depicts the resulting scatterplot between frequency of past DUI convictions and the log of total cortisol response. Inspection of this scatterplot and regression analysis diagnostics indicated that one time DUI offenders were more heterogeneous regarding cortisol responding compared with multiple offenders (i.e. heteroscedasticity). While not invalidating analysis of association, this variance can weaken it. Thus, two runs of correlational analyses were conducted to explore associations between the number of DUI convictions and cortisol response, measures of alcohol commonly employed in DUI assessment protocols, the three Barratt impulsivity measures, and the Millon alcohol dependence and antisocial scales: first with the entire sample, then only with multiple DUI offenders (n = 62). To correct for familywise error from multiple analyses, and given the exploratory nature of this study, a Bonferroni correction was made to maintain an overall error rate of α = 0.1 for each set of correlational analyses. Accordingly, corrected α for inferences of significance was set at 0.006 for each individual correlational analysis. Table 2 summarizes results of these analyses. At this corrected α level, the MAST and the MFQ were significantly correlated to the number of past DUI convictions in the entire sample, with trends for an association with the Millon Alcohol Dependence Scale and cortisol response. In contrast, when only multiple DUI offenders were considered, cortisol, age, and MCV emerged significantly correlated to DUI convictions, with trends for the MAST and AST.

In order to discern the degree to which cortisol response could contribute to DUI frequency prediction, independent of other commonly used indicators, a two-step regression analysis was performed with the multiple-offender group. At the first step, those variables found to be significantly correlated to number of DUI convictions in previous analyses at a liberal uncorrected α (α = 0.05), namely age, MAST, MCV, and AST were entered simultaneously [R = 0.505, R² = 0.255, F(4, 57) = 4.88, P = 0.002]. Then, cortisol response was entered at the next step. The final regression was significantly more predictive [R = 0.588, R² = 0.346, F(5, 56) = 5.92, P < 0.001] than the regression at the first step, with cortisol response adding significantly [F(1, 56) = 7.75, P = 0.007] to the overall variance in the number of past DUI convictions and accounting independently for 9.1% additional variance, or ~25% of the total variance accounted for.

Finally, to clarify the other behavioural characteristics cortisol responses might be associated with, stepwise multiple regression analyses were performed between cortisol responses and the MAST, MFQ, days of risky drinking, MCV, and the antisocial and alcohol dependence scores of the MCMI, first with the entire sample, then with multiple DUI offenders only. In both regression analyses, MCV was the strongest predictor to enter at the first step (P < 0.05), with R = 0.24, R² = 0.06. F(1, 102) = 6.32, P = 0.014 for all participants, and R = 0.31, R² = 0.10, F(1, 60) = 6.57, P = 0.013 for multiple DUI offenders, with no other variables reaching the criterion for entry at a subsequent step.

**DISCUSSION**

The main finding of the present exploratory study was that in a sample of convicted DUI offenders, salivary cortisol response sampled during an experimental protocol was systematically related to frequency of past DUI convictions. This finding was particularly pronounced in multiple DUI offenders, for whom the strength of association between cortisol response and past DUI offences was stronger than all of the commonly employed psychosocial and biological screening measures considered here. Finally, cortisol response appears to contribute uniquely to the variance in the frequency of past DUI convictions.
These findings are original, and are all the more remarkable given the naturalistic context in which cortisol was sampled. Typically, cortisol response studies use standardized psychosocial stressor paradigms that are capable of reliably eliciting neurobiological activity. These include challenges such as mathematical tasks with time constraints and monetary incentives, or public speaking (Panknin et al., 2002; Zimmermann et al., 2004). In contrast, participants in this study were exposed to an experimental protocol involving a variety of tasks and activities, including blood taking, neurocognitive tasks, and psychosocial probing. These experiences, though not specifically contrived to stress participants, elicited cortisol alterations that, when aggregated, were systematically associated to DUI frequency. Detection of reactivity under these conditions in the laboratory is not surprising, as even relatively rudimentary cognitive challenges in this context can elicit significant neurobiological activity (Brown et al., 1988).

Overall, the results suggest that salivary cortisol has the potential of furthering our understanding of the mechanisms involved in DUI recidivism.

Dysregulation of the HPA-axis, reflected specifically by blunted cortisol response, has been noted following alcohol ingestion, and in alcoholics and non-alcoholics with a positive family history for alcohol problems (Gianoulakis et al., 1989, 2003, 2005; Lovallo et al., 2000). At the same time, alcohol abuse and dependency are well-established sentinel characteristics of DUI. Thus, the significant inverse relationship between cortisol response with both the number of past DUI offences and MCV, a measure sensitive to cirrhotic hepatic damage due to longstanding and heavy alcohol consumption (Levi and Chalmers, 1978; Pol et al., 1990), are coherent findings. Testing for acute alcohol consumption as an exclusion criterion for this study further supports this conclusion.

The results also suggest that cortisol response may reflect behavioural components other than those captured by common measures of alcohol abuse. In individuals with multiple DUI convictions, cortisol response was found to explain 9% of additional variance in DUI frequency. This contribution independently represented approximately a quarter of the entire variance accounted for by the linear combination of all other measures found to be individually correlated to DUI frequency. Several characteristics, other than excessive alcohol consumption specifically, have been linked to both attenuated cortisol response and repeat DUI, including antisocial tendencies and impulsivity (McCord, 1984; Lucke et al., 1991; Soloff, 2000; C’d de Baca et al., 2001). However, in this study, analysis failed to uncover any systematic relationships between cortisol response and these behaviours specifically, at least in the manner in which they were assessed here. Thus, the possible reflection of this additional contribution to the variance remains uncertain.

From a slightly different perspective, the gradient between the infrequent DUI offender and the so-called ‘hard core’ multiple offender can be viewed as the increased resistance to therapeutic countermeasures and the obliviousness to the threat of sanction (Yu, 2000; Voas, 2001). In this light, the findings related to cortisol responses and treatment outcome (Kiefer et al., 2002; Junghanss et al., 2003) seem relevant. Studies have found that attenuated cortisol response predicted greater probability of relapse in alcoholics following a period of post-treatment abstinence. Similar to the present study, Junghanss et al. (2003) were also unable to clearly identify other concomitant behavioural features frequently linked to alcoholism and attenuated cortisol response, such as affective status, to explain how cortisol response might mediate the risk of relapse. These investigators speculated that a diminished cortisol response during early abstinence, rather than being a result of disturbed HPA-axis function due to heavy alcohol consumption, could be a marker for a more dependent drinking pattern with a higher risk for relapse. Interestingly, a recent study (O’Malley et al. 2002) has explored whether naltrexone-induced opioid-receptor blockade and the subsequent increase in HPA-axis activity with increased cortisol levels could be linked to decreases in drinking and craving in alcoholics.

O’Malley and his colleagues found a negative correlation ($r = -0.53$) between the perceived intensity of alcohol craving and cortisol level. To these observations, the current study contributes support for a biological mediator of DUI offending that, in both human and animal studies, has been found to influence both alcohol consumption and its reinforcing effects (Gianoulakis et al., 2003). Practically, these lines of evidence suggest that in the DUI context, ‘intervention resistance’ may not be fully captured by screening measures sensitive to the degree of psychosocial disturbance and alcohol dependency (e.g. the MAST and AUDIT), or biological indices that reflect hepatic alterations with severe and chronic drinking (e.g. MCV). Rather, the relationship between intervention resistance (i.e. as reflected by increasing frequency of past DUI convictions) and cortisol response may in part be owing to a more biologically based alcohol use style, perhaps characterized by heightened perceptions of craving.

**Further considerations**

The reason for the stronger association between cortisol response and DUI frequency in multiple DUI offenders vs the entire sample seems owing to statistical artefact. That is, the greater variability in cortisol response in one-time offenders compared with multiple offenders weakened the analyses of association (i.e. heteroscedasticity). Why ‘first time’ offenders (i.e. first time convicted) were a more diverse subgroup than repeat offenders is speculative. However, it is likely that a proportion of the former were probably ‘accidental’ offenders who do not have important alcohol use problems or who can avoid reconviction through successful self-regulation, and thus may be unlikely to experience a re-conviction. Others in this group were likely to be incipient recidivists, or chronic DUI recidivists who had serendipitously experienced only one brush with the law. In contrast, the multiple DUI offenders appeared to represent a more homogeneous subgroup in which the putative neurobiological characteristics associated with problematic drinking and/or repeated reconviction, such as cortisol response, were more firmly established. In summary, by including one-time offenders, relationships between cortisol response and past DUI conviction frequency were weakened. At the same time, the variability in cortisol response in first time offenders invites further investigation of the potential of cortisol to sort out the individuals who go on to be repeat offenders.

A contrasting trend was observed with MAST and MFQ that were significantly associated with DUI frequency when one-time DUI offenders were included, but not when multiple offenders were isolated. The MAST and MFQ both document self-reported past DUI convictions that contribute directly
to the calculation of aggregate scores. Thus, finding a relationship between MAST and MFQ scores and DUI frequency seems obvious. It is noteworthy, therefore, that when isolating individuals who pose greater risk (i.e. multiple offenders), both the MAST and MFQ performed relatively poorly. Overall, this observation suggests that in high-risk multiple DUI offenders, (i) the relationship between frequency of past DUI convictions and self-reported symptoms and consequences related to excessive drinking is not as consistent as in one-time offenders; and (ii) common self-report measures are less reliable in individuals at high risk for repeat offending compared with biological indices.

These results are based upon a cross-sectional study methodology and, though compelling, must be considered as preliminary. Replication of the findings, under more controlled experimental conditions and using a more standard stress paradigm, is now underway. We hypothesize that study replication in this fashion will produce even stronger relationships between cortisol response and DUI conviction history. Moreover, the importance of cortisol response to the clarification of both the mechanisms underlying repeat offending and treatment resistance will emerge only if cortisol responses are capable of predicting future DUI events using a prospective study design. On a practical level, early identification of those individuals who are less likely to maintain behavioural changes related to alcohol use and driving, in spite of common DUI countermeasures and/or punitive sanctions, would be one way in which to reconsider how to better match intervention strategies to individual characteristics and improve outcomes (Wells-Parker et al., 1989).

This study employed a recruitment strategy to reduce sampling bias inherent in studies of treatment or remedial programme participants. Our strategy seemed effective, as the proportion of individuals in this sample who were non-compliant with remedial measures and sanctions is similar to that observed in other studies of compliance in the DUI population (Voas, 2001; Brown et al., 2002). Moreover, the prevalence of substance use disorders, as indicated by converging diagnostic interview outcomes, psychosocial assessment, and biological markers, fall within the range of estimated population parameters reported in other prevalence studies (Korzec et al., 2001).

Other sources of sampling bias are not as easily resolved. Bias from self-selection for study participation is unavoidable. Moreover, convicted DUI offenders do not represent the entire population of drunk drivers. DUI arrest and conviction rates are also susceptible to the influence of several factors, including geographic, legal, socioeconomic, and enforcement dispositions. Whether the present findings would be obtained in another jurisdiction, with, for example, a lower blood alcohol content (BAC) threshold for a DUI arrest than the current 0.08 in Quebec, is uncertain. Finally, the predominantly white Caucasian sample may limit the generalizability of the findings to other more ethnically and culturally diverse populations.

Acknowledgements — The authors would like to acknowledge the exemplary collaboration of Lyne Vézina and Andrée Brassard of the Quebec Licensing Bureau, as well as the efforts of Lucie Legault in the management of the protocol. Funding for this study was received from the Fonds de recherche sur la nature et les technologies (Research funds on nature and technologies), Ministère des Transports du Québec (Quebec Ministry of Transport), Société de l’assurance automobile du Québec (Quebec Licensing Bureau), and Canadian Safety Council. A research scholar career grant from the Conseil Québécois de la Recherche Sociale (Quebec Social Research Council) was awarded to T.G.B.

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