BMJ Open

Health assessment of commercial drivers: a meta-narrative systematic review

Abd Moain Abu Dabrh,[1] Belal Firwana,[2,3] Clayton T Cowl,[1] Lawrence W Steinkraus,[1] Larry J Prokop,[4] Mohammad Hassan Murad[1,2]

To cite: Abu Dabrh AM, Firwana B, Cowl CT, *et al*. Health assessment of commercial drivers: a meta-narrative systematic review. *BMJ Open* 2014;**4**:e003434. doi:10.1136/bmjopen-2013-003434

▸ Additional material is available. To view please visit the journal http://dx.doi.org/10.1136/bmjopen-2013-003434.

Received 18 June 2013
Revised 27 January 2014
Accepted 10 February 2014

For numbered affiliations see end of article.

Correspondence to
Dr Abd Moain Abu Dabrh; abudabrh.abdmoain@mayo.edu

ABSTRACT

Background: Motor vehicle accidents associated with commercial driving are an important cause of occupational death and impact public safety.

Objectives: We summarise the evidence regarding the type, prevalence and impact of medical conditions discovered during health assessment of commercial drivers.

Evidence review: We conducted a systematic review of multiple electronic databases and made a manual search for relevant studies that enrolled commercial drivers in any country and reported the outcomes of health assessment carried out in the context of commercial driving through November 2012. Data were extracted by a pair of independent reviewers and synthesised using a metanarrative approach.

Results: We identified 32 studies of moderate methodological quality enrolling 151 644 commercial drivers (98% men). The prevalence of multiple health conditions was high (sleep disorders 19%, diabetes 33%, hypertension 23% and obesity 45%). Some conditions, such as sleep disorders and obesity, were linked to increased risk of crashes. Evidence on several other highly relevant medical conditions was lacking. Cost-effectiveness data were sparse.

Conclusions: Several medical conditions are highly prevalent in commercial drivers and can be associated with increased risk of crashes, thus providing a rationale for health assessment of commercial drivers.

Strengths and limitations of this study

- This systematic review followed a rigorous methodological approach to summarise the type, prevalence and impact of medical conditions discovered during health assessment of commercial drivers.
- Data were insufficient to conduct quantitative analysis and provide pooled estimates.
- The available evidence is at high risk of bias due to reporting and selection biases.

INTRODUCTION

Driving commercial motor vehicles is defined as a class of professional driving that requires a special license and qualifying skills to operate on certain types of machineries for commercial use.[1] In the USA only, there is an estimated 11.4 million commercial vehicle drivers.[2] Transportation accidents, particularly roadway accidents, are considered as the cause of workplace deaths, contributing to about 41% of deaths among all-cause deaths.[3] In 2012, commercial driving was reported as the leading causes of occupation-related deaths among all-occupational deaths accounting for about 50% of all-work injury deaths.[3] It accounts for third highest fatal occupation. Motor carriers employing commercial drivers encounter steep economic consequences from accidents resulting from impaired or incapacitated drivers.[4] For example, it is estimated that each accident where the driver involved had an obstructive sleep apnoea syndrome (OSA) would approximately cost US$59 000 in direct costs and liability.[5]

The Federal Motor Carrier Safety Administration (FMCSA) is an agency within the US Department of Transportation (DOT) charged with regulating interstate commerce involving commercial motor vehicles. The FMCSA has published statutory regulations for commercial drivers, mandating a medical examination at least every 2 years, and more frequently for drivers with specific medical conditions that require more frequent follow-up. The medical regulations in the USA differ from other countries. Commercial driving vehicle collisions have resulted from various health-related events or condition,[6] including sleep disorders (eg, OSA),[7] fatigue,[8] diabetes mellitus (DM),[9] hypertension and the use of illicit drugs, making the commercial driving medical examination a major individual and public safety priority. OSA is a significant health problem that is estimated to affect about 20% of adults in general population[10] and

about 28% of commercial drivers.[11] OSA can cause daytime sleepiness, fatigue and poor concentration, as well as night-time snoring and restlessness, all of which is attributed to sleep arousals and poor-quality sleep. Hypertension has also been associated with increased risk for acute life-threatening events, thereby resulting in higher crash risk.[12] The prevalence of obesity among commercial drivers may also result in musculoskeletal compromise, and the association with elevated body mass index (BMI) and crashes has been documented.[7] These and other medical conditions pose potential risk for the drivers and other individuals on the road while the driver is on duty.

The impact of interventions to evaluate and assess fitness-to-drive among drivers in general population with chronic conditions was studied.[13] A prior systematic review concluded that certain clinical and neuropsychological tests lacked sufficient evidence in predicting fitness-to-drive end points, or the ability to reduce motor vehicle crashes in drivers with chronic disabilities.[13] The evidence, however, continues to be conflicting, particularly involving commercial motor vehicle drivers. For example, the association between untreated OSA and motor vehicle collision rates is well identified,[14] and well-managed OSA has been associated with decreased collision rates.[15] Conditions such as hypertension, obesity, fatigue and DM have all been found in many commercial drivers involved in accidents.[12] However, determining a cause–effect relationship between these medical conditions and crash cases can be challenging.

In this systematic review, we aim to appraise and summarise the existing evidence regarding the health assessment of commercial drivers including various types of examinations for fitness-to-drive. We plan to evaluate the outcomes of these assessments in terms of prevalence and type of conditions detected, the economic impact of these conditions and their association with crashes, and how they are diagnosed in commercial drivers. Such information can provide a rationale for the fitness-to-drive examination and help policymakers and clinicians conducting these examinations.

METHODS

The analytical framework of this meta-narrative review is depicted in figure 1. We hypothesised that the finding of prevalent conditions in commercial drivers that can be associated with increased risk of crashes and can be readily diagnosed would provide the rationale for the fitness-to-drive examination. Possible downsides and burdens of such examination are also presented in the framework. We also aimed at searching for diagnostic tests evaluated specifically in this population since the diagnostic accuracy of tests may be different in commercial drivers than the general population (due to different disease prevalence, comorbidities, issues with under-reporting, etc). If we only find sparse evidence about conditions known to impact driving, such gap in the evidence would provide research agenda for future studies in commercial drivers.

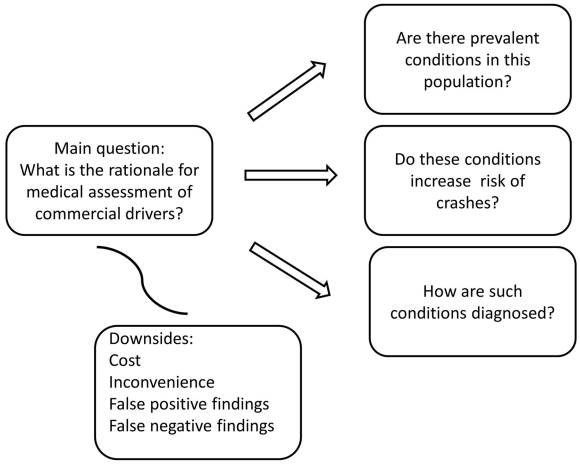

Figure 1 Analytical framework.

Literature search and study eligibility

We included original observational studies, prospective and retrospective studies that enrolled commercial drivers screened to evaluate their fitness-to-drive regardless of the country of origin. Economic studies that assessed costs related to physical examinations or crash costs in commercial drivers with medical assessment history were also included. Health assessment and evaluation search terms included physical examination, visual acuity tests, drug screening, sleep pattern and fatigue syndromes assessments, health questionnaires in relation to driving risks and psychological and neurological evaluations. Studies that examined drivers through driving tests, on the road or through driving-simulation scenarios, were also included. We expanded the search to include a broad spectrum of health-related conditions studied in commercial-vehicle drivers, acute or chronic; however, OSA, hypertension, obesity, alcohol misuse, use of illicit drugs and diabetes were the most prevalent studies identified. We expanded the search to include all languages, with last date of inclusion to be November 2012.

A comprehensive literature search was conducted by an expert reference librarian with input from a study investigator with experience in systematic reviews (MHM). The search included the electronic databases MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, CINAHL and Scopus, using various combinations of controlled vocabulary supplemented with key words. We also searched FMCSA documents and website for additional references, and to examine the current non-discretionary and discretionary medical requirements. Two reviewers (AMAD and BF), working independently, identified original studies eligible for further review by screening abstracts and titles. If a study was deemed relevant, the manuscript was obtained and reviewed in full-text versions for further assessment.

Previously described data sources, including citing articles and relevant systematic reviews were searched manually for possible studies, and duplicates were excluded.

Data extraction

Two reviewers independently extracted data. We extracted data on patients' demographics, baseline characteristics, study design variables, sample size, intervention type, study medical examination focus and outcome measures when reported. In addition, for each study, we extracted variables related to the medical history or the physical examination that were used for assessment, including blood pressure (BP) measurements, BMI, neck measurements, history of chronic illness and disease-specific scores, when possible.

Risk of bias assessment

We used The Newcastle-Ottawa Scale (NOS)[16] to appraise the risk of bias (methodological quality) of the included studies. For diagnostic studies, we used the QUADAS tool.[17] For economic studies, we used the National Institute of Health and Care Excellence (NICE) and Consolidated Health Economic Evaluation Reporting Standards (CHEERS) guidelines.[18 19] For cross-sectional studies, we evaluated patient selection, reference standard and inclusion of index cases, standardised follow-up and robustness of outcome ascertainment.

Data synthesis

After conducting the literature review and thoroughly observing the methodological heterogeneity between studies, and the non-standardised use of the commercial driver's license medical examination, insufficient reporting of effect size of measurements and diversity in range of data sources, we synthesised the evidence using a meta-narrative approach according to the RAMESES guidelines[20] and did not pursue meta-analysis. A meta-narrative systematic review follows the phases of planning, search, mapping, appraisal and synthesis. Synthesis phase consists of identifying the key dimensions of the problem, providing a narrative account of the contribution of each dimension, explaining conflicting findings and considering the higher order data. Data are presented using descriptive statistics and or narratively without quantitative pooling.[20] For the purpose of this review, we considered the various terms used for the medical evaluation of commercial drivers interchangeable (eg, commercial driver's license physical examination, fitness-to-drive, health assessment and evaluation, etc).

RESULTS

We included 32 studies (figure 2) that enrolled 151 644 drivers (age 28–63; 98% men, with a majority of Caucasian or Asian ethnicity). Table 1 summarises and

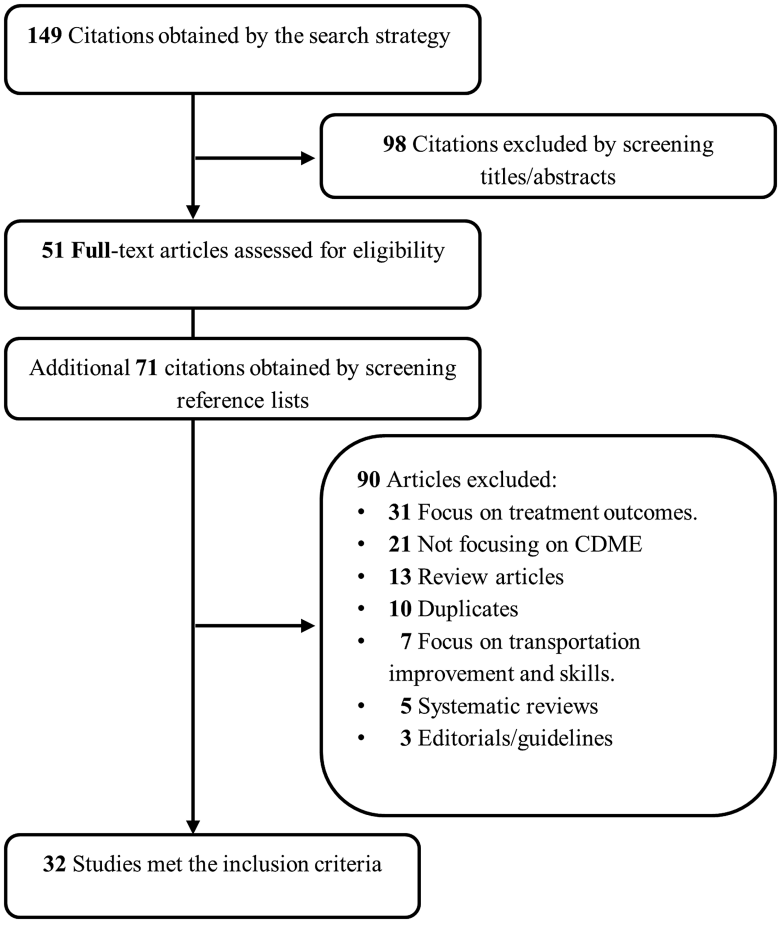

Figure 2 Flow chart of the literature search.

Table 1 Description of the included studies

Study ID	Origin	Study design	Duration/period	(n)	Intervention/diagnostic/analysis method	Health evaluation focus
Sunwoo (2012)[21]	USA	Diagnostic	NR	372	Diagnostic: MSLT vs PVT and DADT	Sleep assessment
Sharwood (2012)[22]	Australia	Cross-sectional	November 2008–December 2010	517	Diagnostic	Assessment of self-report vs home-monitor device
Hayano (2012)[23]	Japan	Diagnostic	February 2006–August 2007	165	PSG; ACAT was utilised	Screening of sleep-disordered breathing
Gjerde (2012)[24]	Norway	Cross-sectional	October 2008–May 2009	6187	Diagnostic tests of alcohol and drug misuse	Oral fluid samples were analysed for alcohol and drug % using Statsure diagnostic test
Xie (2011)[25]	USA	Case–control	January 2007–December 2008	1890	H&P plus JTF OSAS criteria	OSAS risk factors
Smith (2011)[26]	USA	Cross-sectional	9 months of data collection	595	Berlin Sleep Questionnaire	OSAS screening
Morales (2011)[27]*	USA	Cross-sectional	NR	77	▶ Actigraphy ▶ In-home, type-II PSGs	Identify drivers with short sleep durations
Braeckman (2011)[28]	Belgium	Cross-sectional	NR	476	Questionnaire, PSQI, ESS, and BQ	Sleep quality and diagnosis of EDS
Stanley (2010)[29] *	USA	Cross-sectional	January 2007–December 2009	101	Maintenance of Wakefulness Test	Prevalence of microsleep
Nolte (2010)[30] *	USA	Cohort	NR	23	Berlin, ESS, SF-36, FOSQ	OSAS monitoring adherence
Doyle (2010)[31]	USA	Cohort	August 2007–May 2008	208	Educational mailings, installation of BP machines at bus terminals, access to free dietitian consultations and gym memberships	Improve BP control
Riva (2010)[17] *	Italy	Cross-sectional	2008–2010	226	Application of an experimental survey protocol: medical examination, questionnaires for the main risks, instrumental and laboratory tests (ECG, eye test, audiometric test, blood test, urinary drugs test)	Health surveillance in order to assess fitness-for-work
Asaoka (2010)[33]	Japan	Diagnostic	April 2004–March 2005	432	ESS (Japanese version) and subjective screening	EDS
Morales (2010)[34]*	USA	Cross-sectional	NR	39	Simulation of medical-certification exam and in-home type-II PSGs	OSA screening
Vennelle (2010)[35]	UK	Cross-sectional	NR	677	ESS questionnaire	Prevalence of daytime sleepiness
Tanaka (2009)[36]	Japan	Diagnostic	April 2005–March 2006	803	Diagnostic: Questionnaire (ESS)+Pulse Oximetry (PO)	assessment and validity of SAS questionnaire and PO
Parks (2009)[37]	USA	Diagnostic	January 2007–August 2008	456	▶ JTF/consensus criteria screening ▶ Suspect OSAS were referred for PSG	OSAS screening
Redelmeier (2009)[38]	Canada	Case-control	January 2005–January 2007	795	Blood glucose monitoring including HbA1c	Diabetes control
Watkins (2009)[39]	USA	Diagnostic	September 2007–October 2008	346	▶ Portable OSAS screening device (RUSleeping) ▶ PSG (gold standard)	OSAS screening

Continued

Table 1 Continued

Study ID	Origin	Study design	Duration/period	(n)	Intervention/diagnostic/analysis method	Health evaluation focus
Greene (2009)[40]	USA	Economic	NR	499	Economic simulation model	Economic impact of blood pressure control programme
Lemos (2009)[41]	Portugal	Cross-sectional	March 2007–July 2007	209	Sociodemographic and Berlin questionnaire	OSAS prevalence and risk factors
Weigand (2009)[7]	USA	Cohort	NR	103	Eye-detection multicamera for sleep/fatigue assessment technology	Fatigue and BMI evaluation
Martin (2009)[42]	USA	Cross-sectional	January 2004–December 2005	2849	Costs and disease prevalence compared normal weight, overweight and obese	Standardised general DOT examination
Talmage (2008)[43]	USA	Cross-sectional	October 2006–October 2007	1443	Questionnaire about OSAS risk factors and Epworth Sleepiness Scale score	OSAS screening
Harshman (2008)[44]	USA	Case-control	24 months	499	BP *DownShift* Program	Improve BP control
Zaloshnja (2007)[45]	USA	Economic	1998–2000	NR	Safety programmes	Cost estimates of MV-related and non-MV related, on and off-job site
Canani (2005)[46]	Brazil	Cross-sectional	January 2000–December 2002	438	Questionnaire including EES	Sleepiness prevalence
Spicer (2005)[47]	USA	Cross-sectional	January 1983–June 1996	108 360	*PeerCare* program (occupational peer group to achieve a cultural shift from enabling working under the influence of drugs or alcohol to maintaining a substance-free workplace.)	Drug testing/screening
Gurubhagavatula (2004)[48]	USA	Diagnostic	NR	1329	▶ Symptoms, BMI, plus Oximetry ▶ PSG (gold standard)	OSAS screening
Laberge-Nadeau (2000)[9]	Canada	Cohort	1987–1991	13 453	Telephone survey of mandatory fitness-to-drive physical evaluation	Fitness-to-drive
Laberge-Nadeau (1996)[6]	Canada	Nested case-control	January 1985–December 1990	1121	Diagnostic: Medical and Crash Records/reports and review of mandatory fitness-to-drive physical evaluation	Medical and ocular conditions in relation to crash severity and econometric analysis
Dionne (1995)[49]	Canada	Nested case-control	January 1987–December 1990	6190	Diagnostic: Medical and Crash Records/reports and review of mandatory fitness-to-drive physical evaluation	Medical and Ocular conditions in relation to crash severity and econometric analysis

*Published only as an abstract.
ACAT, auto-correlated wave detection with adaptive threshold; BMI, body mass index; BP, blood pressure; DOT, Department of Transportation; EDS, Excessive daytime sleepiness.

describes the included studies. Online supplementary table S1 summarises the baseline characteristics of included studies.

The studies examined different health conditions, except for four studies, that combined more than one medical condition; 19 studies concentrated on OSA or other sleeping disorders, three studies on hypertension or BP control programmes, two on DM and four were related to studying the use of drug and alcohol consumption. There were three economic and cost-effectiveness studies in different conditions in commercial drivers. Included studies contained different designs; 16 studies were cross-sectional, 7 diagnostic studies, 4 cohort studies and 5 case–control studies. Three of the 16 cross-sectional studies were economic studies. Seventeen of 32 studies originated from the USA. Online supplementary table S2 describes the methodological quality of the included studies. The overall quality of the body of evidence was moderate to low. The main findings of included studies are summarised in table 2.

Prevalence data

Sleep disorders were present in 19.2% (n=2674) of the participants. OSA constituted the main sleep disorder. DM prevalence was 33.4% (n=16 138), with a mean crash rate of 25% (table 2). The average BMI was 30.5 ±6 kg/m² and mean age of 47 years, with no clear distinction of diabetes type. The prevalence of hypertension was 23% (n=1000, mean age 43, BMI≥30 kg/m²). The prevalence of alcohol and/or illicit drug use was 0.3% (n=6413), compared with 5.4% of car and van drivers[24 32] The prevalence of overweight and obesity was 78.4% and 45.2%, respectively.

We did not find studies that reported on other highly relevant medical conditions, such as seizure syndromes, hearing and visual impairments (one study on binocular vision) or chronic kidney disease.

Association with crashes

Studies generally agreed on finding an association between obesity and the risk of crashes. This was more evident in the presence of comorbidities, especially with concomitant sleep disorders and fatigue syndromes.[7] A systematic review demonstrated that treatment of OSA with continuous positive airway pressure reduces the risk of crashes by 72%.[15]

Patients with DM were at increased risk of crashes; and[6 25 38] also at increased risk of OSA and more prone to accidents when compared with those with no diabetes (16.2%; OR 2.03, CI 1.51 to 5.70).[25] The use of insulin, oral hypoglycaemic agents or both showed an increased relative risk of crashes, as did low glycated haemoglobin (HbA1c) quartiles and severe hyperglycaemia requiring an outside assistance (OR=4.07, 95% CI 2.35 to 7.04).[38] Bus or truck drivers with diabetes showed no significant relationship with crash severity.[38]

Hypertension in bus drivers and binocular vision problems in truck drivers were associated with increased crash severity.[9] Surprisingly, illicit drug use was not linked to increased risk of accidents.[32]

Diagnostic strategies

Various sleep screening tests and questionnaires (see online supplementary table S3) including Epworth Sleepiness Scale,[28 30 33 35 36 43 46] Berlin questionnaire[26 30 41] and the Consensus Criteria[50] were used to evaluate the presence of sleep disorders in commercial vehicle drivers, the latter showing marked sensitivity in this setting.[25 37 43] Other modalities were less commonly used (polysomnography, actigraphy, analysis of cyclic variation of heart rate from automated ECG and the Multivariable Apnoea Prediction Index).[22 23 27 34] Some studies used on-road vehicle motion data as well as video of the drivers and the surrounding environment to analyse driving or patterns while driving.[7]

A program that couples diagnosing hypertension with an intervention (the *DownShift program*) was associated with improved BP control and use of medications, high participant satisfaction and low risk of driver's disqualification.[31 44] Various screening tests were used to evaluate illicit drugs and alcohol misuse.[24 32] In general, there was limited evidence favouring a particular strategy in commercial drivers beyond what is known from studies in the general population.

Economic impact

Screening for OSA in commercial drivers using polysomnography was found not to be cost-effective (more expensive than the cost of crashes when no screening is carried out). However, a stratification approach using BMI, age and gender with subsequent confirmatory in-lab polysomnography for high-risk drivers was cost-effective if 74% of those diagnosed accepted treatment.[51]

Overweight and obese truck drivers were found to have significantly higher annual healthcare cost when compared with normal weight participants.[42] These individuals had higher prevalence of hyperlipidaemia, diabetes and hypertension,[42] suggesting possible cost saving if screening and management of obesity lead to reduction in the incidence of obesity complications.

In hypertension, the economic impact of the 2-year BP *DownShift* program showed cost savings and cost reduction when compared with the pre-BP *DownShift* phase to the utility company studied.[40] These data are from a single study; however Zaloshnja *et al*[45] reported the annual employer cost of motor vehicle crashes in which at least one driver was alcohol-impaired was over US$9 billion and reported significant costs related to crashes while on job, as well as for workplace violence-related injuries.

DISCUSSION

We conducted a systematic review of the literature and demonstrated that several conditions are significantly prevalent in commercial drivers and can be associated

Table 2 Summary of the main findings of included studies stratified by condition

Prevalence	Crash association	Diagnostic/intervention strategies	Economic impact
Sleep disorders			
▶ Sleep disorder diagnoses were present in about 19.2% (n=2674); however. OSA constituted the main sleep disorder diagnosed in these studies ▶ Although the prevalence of sleep apnoea distribution differed between studies, yet higher prevalence was observed in commercial vehicle drivers than general populations, with and without associated risk factors ▶ Drivers with a reported history of hypertension were 2.5 times more likely to have OSA as compared with those with a normal blood pressure (OR 2.57 CI 1.67 to 3.96)[25] Hypertension correlated with feeling tired or postsleep fatigue (p<0.05)[26]	▶ The presence of sleep disorders was found to increase risk of crashes ▶ Obesity with BMI≥25 is associated with a 14-fold increased risk of OSA (OR 13.64)[41] and BMI≥30 had more than a 25-fold increased risk of OSA (OR 26.86).[25] Obesity with BMI≥25 is associated with an increase of 2.5 times in sleep apnoea≥2 days/month (OR 2.53, CI 1.44 to 4.59) and correlated with snoring loudness (the louder the snoring, the greater likelihood of obesity; p<0.05)[26] ▶ BMI in commercial drivers was found to be associated with increased risk of OSA (Spearman and Pearson correlation coefficients were 0.41 and 0.30 respectively)[34]	▶ The Berlin questionnaire predicted strong correlation between sleepy driving and the severity of snoring and witnessed apnoea, while witnessed apnoea had no correlation with BMI, gender or hypertension.[26] ▶ 4% ODI4 revealed strong correlation with OSA severity (Spearman Rank 0.86 and Pearson correlation coefficients 0.95)[34] ▶ MAP index had the 2nd strongest correlation with OSA severity after ODI4 (Spearman Rank and Pearson correlation coefficients were 0.59 and 0.53, respectively)[44] ▶ CVHR using automated ECG might help screening moderate-to-severe SDB[23] ▶ The Multivariable Apnoea Prediction Index showed poor agreement with the home-monitor detected sleep apnoea (AUC 0.58, 95% CI 0.49 to 0.62). only 12% of drivers reported daytime sleepiness (Epworth Sleepiness Scale score>10)[22]	▶ Gurubhagavatula *et al*[51] estimated the cost of crashes involving commercial drivers to support screening and treatment of OSA, the total costs per driver of programmes arising from comprehensive screening, treatment of identified cases of OSA, and crashes varied based on treatment acceptance rates and stages of diagnosis screening —if treatment acceptance is 100%, then the total costs per driver are; do nothing: US$689; one-stage screening: US$562; two-stage screening: US$587 and with polysomnography US$920
Diabetes mellitus			
▶ 16 138 drivers enrolled with 33.4% having a diagnosis of diabetes mellitus[9 25 38] ▶ Prevalence rate of collisions or crashes at 25% ▶ Average BMI was 30.5±6 kg/m² ▶ In two studies,[9 38] 68% of total drivers with diabetes were on insulin and about 40% reported diabetes with complications	▶ Truck drivers with diabetes were found to have more accidents than a control group (t-statistic 2.42, coefficient 0.84) ▶ Levels of severe hypoglycaemia requiring outside assistance that showed almost quadrupled relative risk of crash (OR=4.07, 95% CI 2.35 to 7.04)[38] ▶ Crash risk increased in ST drivers group of uncomplicated patients of diabetes who were not using insulin when compared to a healthy cohort (RR 1.68, CI 1.27 to 2.24); but with none of the AT drivers group[9]	▶ Low HbA1c quartiles correlated with higher relative risk of adverse consequences and increased crashes risk in adults with diabetes mellitus (OR=1.27, 95% CI 1.04 to 1.55) after adjusting to confounders ▶ Levels of blood sugar, especially the diagnosis of severe hypoglycaemia was found with drivers with increased risk of accidents	▶ NR

Continued

Table 2 Continued

Prevalence	Crash association	Diagnostic/intervention strategies	Economic impact
Hypertension ▶ In 1000 commercial drivers in three studies, 23% had a hypertension diagnosis ▶ The mean age of drivers was 43, with a mean BMI≥30 kg/m²	▶ Hypertension had no effect on crash rates[6]; however, Nadaeu *et al* in a follow-up study, the same authors found that bus drivers with hypertension were involved in more severe crashes in comparison to healthy bus drivers[9]	▶ Studies applied the *DownShift* program intervention to their population to examine the effect size[31 44] ▶ 58% of 208 drivers were controlled to BP<140=90, compared to 38% at baseline (p<0.001)[31] ▶ There were significantly fewer employees having uncontrolled blood pressure according to FMCSA guidelines (17.2%) than they had before *DownShift* program implementation (26.1%, p<0.01), even in drivers with other concomitant comorbidities[44]	▶ Greene *et al*[40] studied the economic impact of the 2-year BP *DownShift* program and reported a 16.3% reduction in costs for a sample of 499 CDL employees over 2 years (pre-BP *DownShift*: US$3 312 220; post-BP *DownShift*: US$2 771 094). ▶ Cost savings to the utility company from implementation of the BP *DownShift* program for these 499 employees was US$541 126 over the 2 years or about US$271 000 annually
Alcohol or illicit drugs misuse ▶ A total of 0.3% of surveyed commercial drivers was found to be positive for alcohol or drug levels[24 32] ▶ *Gjerde et al*[24] reported that levels of alcohol and drugs were lower among commercial drivers in comparison to non-commercial drivers	▶ Riva *et al*[32] reported no statistical significance between drug consumption and decreasing accidents or minimising the risk on public safety	▶ Spicer *et al*[47] the implementation of support and peer-focused substance abuse intervention programmes was found to help minimising workplace injuries ▶ The detection of a psychoactive substance in a sample from a truck driver compared with car or van driver was 0.29 (95% CI 0.17 to 0.53). The adjusted OR for the detection of an illegal drug was 0.42 (95% CI 0.18 to 0.82), and the adjusted OR for the detection of alcohol was 0.13 (95% CI 0.02 to 1.10)[24] ▶ Employee alcohol-involved injury safety and prevention programmes are likely to be helpful to minimise employer fringe costs without reducing employees' benefits[45]	▶ Zalonshnja *et al*[45] found that the annual employer cost of motor vehicle crashes in which at least one driver was alcohol impaired was over US$9 billion, including wage-risk premiums; of this, only US$3.1 billion comes from job-related alcohol involvement and 30% of it was directed towards paying for legal liabilities ▶ The annual employer cost of alcohol-involved workplace violence-related injuries was more than US$8.5 billion, including wage-risk premiums; of this, more than 52% covered wage replacement costs and another 40% covered wage premiums
Obesity or BMI-related status ▶ BMI of 25 kg/m² or greater was found in 78.4% of commercial drivers, and 45.2% had BMI≥30 kg/m²	▶ Wiegand *et al*[7] found obese that drivers were at greater risk to be involved in safety-threatening event in	▶ The obese drivers demonstrated signs of fatigue when involved in at-fault incidents (OR 1.99; CI 1.02 to 3.88)	▶ Martin *et al*[42] found that in 2849 truckers had a mean annual total healthcare cost of US$1785.

Continued

Table 2 Continued

Prevalence	Crash association	Diagnostic/intervention strategies	Economic impact
▲ Obese drivers were more likely to have snoring loudness, and reported drowsy driving (p<0.05)[26]	comparison with non-obese drivers (OR 1.37; CI=1.19 to 2.18)	▲ Body mass index (BMI) in commercial drivers was found to be associated with increased risk of OSA (Spearman and Pearson correlation coefficients were 0.41 and 0.30, respectively)[34] ▲ Elevated BMI was found to be correlated with increased risk of sleep aponea.[48] BMI≥25 associated with 14-fold increased risk of OSA (OR 13.64)[41] BMI≥30 had more than a 25-fold increased risk of OSA (OR 26.86)[25]	Unadjusted trimmed total cost for overweight participants (US$1613) and obese participants (US$1792) were significantly higher than for normal weight participants (US$1012; p<0.05) ▲ Adjusted total costs of obese and overweight participants had on average, US$591 (p=0.031) and US$383 (p=0.188) were than normal weight participants

AT, articulated-truck; AUC, area under the curve; BMI, body mass index; CVHR, cyclic variation of heart rate; MAP, Mean arterial pressure; ODI, oxygen desaturation index; OSA, obstructive sleep apnoea; SDB, sleep-disordered breathing; ST, single-truck.

with increased risk for crashes. There were limited data about the burden, cost and possible down sides of the fitness-to-drive examination. Health assessment of commercial drivers seems to be well justified although more studies are needed to provide evidence for the best diagnostic strategies in this population. We did not find studies about several conditions that are highly relevant to driving (eg, seizure disorders, visual impairment, substance abuse and others) likely due to under-reporting. Individuals with or at risk of these conditions are either not allowed to drive commercially or choose to not enrol in screening studies. Cost-effectiveness data are limited but seem favourable when a staged diagnostic approach is used for OSA or when screening was associated with an intervention to control hypertension.

There are several challenges that face commercial vehicle drivers and their medical examiners. Drivers tend to under-report OSA symptoms[22] because of their concerns about losing their certification and also because of the lengthy and expensive subsequent tests that may not be covered by insurance or employer; and also due to loss of income during the medical evaluation. However, several studies[21 23 25 26 34 37 39 43] tested the effectiveness of single and in-home adherence-monitored sleep disorders testing and therapy and found it to be helpful. Reporting and selection bias affected these studies as they depended on subjective reporting or enrolled drivers with more severe conditions. Varying definitions of sleep disorders are also another challenge.

Evaluating and managing commercial drivers with diabetes remains controversial. Risk of crashes can increase in those with uncontrolled diabetes and in those with tightly controlled diabetes at risk of hypoglycaemia.[38] Drivers with diabetes are likely to have other confounding conditions such as OSA, suggesting that the crash risk is not solely due to diabetes. In the USA, patients with insulin-requiring diabetes are not allowed to drive commercially, except under stringent waiver criteria. The link of diabetes and crashes itself has been questioned by the latest report by the FMCSA examining evidence from the medical expert panel.[1] Laberge-Nadeau *et al*[9] suggested that the lack of consistent association between crash risk and diabetes in commercial drivers may be due to 'healthy worker effect'. Diabetes treatment, with oral hypoglycaemic agents but not with insulin, was found to be associated with crashes.[9 38] This may be explained by drivers using varying diets at times (trying to pass the examination) or by inaccurate reporting of the type of medication they use.

Drugs and alcohol misuse, not a rare problem in the general population, is under-reported in commercial drivers.[52] In the absence of regular and random drug testing surveillance, this low incidence is likely due to under-reporting because of fear of losing certification.

Engaging employees in the development and execution of interventional programmes is one approach that was found to be helpful. The use of programs such

PeerCare alcohol program[47] and BP *DownShift program*,[31 44] for hypertension management showed not only health benefits but also provided evidence for how employees are capable of lowering healthcare costs.

The presence of concomitant medical conditions is thought to be associated with a higher risk of crashes.[25] This increased risk can be attributed to complications of the comorbid conditions (cardiovascular event) or due to aggressive management of conditions by drivers in fear of losing their license, which can increase the burden of treatment, side effects and drug interactions.

The type of vehicle is another factor that may affect how comprehensive or detailed the medical examination should be. The severity of crashes varies between vans, trucks and buses. Bus accidents have been found to be more severe, linked with more deaths and possess a greater public safety hazard. There has been a call for stricter regulations to qualify bus drivers.[12]

There is paucity of evidence when it comes to diagnosis of medical conditions in commercial drivers. Thus, diagnostic evidence is derived from the general population. The prevalence of certain conditions may be different in commercial drivers, thus affecting the diagnostic accuracy of the tests. Some studies found a single diagnostic test to be sufficient,[25 37 39 43] whereas a systematic review by Marino *et al*[13] concluded that single screening tests cannot be used to evaluate fitness-to-drive. This review highlighted the lack of evidence to support the use of existing clinical and neuropsychological screening tests and called for developing and validating new tests for drivers with chronic conditions. In addition, there is paucity of evidence regarding the relationship between health conditions and crash risk and the best way to evaluate which drivers are safe with a given condition and which are not.

This systematic review has several limitations. The different designs of included studies made in attempts to reduce heterogeneity statistically implausible. Many of the studies are cross-sectional which limits inference and establishing causality. Even in the cohort studies, the lack of concrete definition of healthy controls and the selection of higher risk groups might cause bias. We were unable to test for publication and reporting biases, which are likely when dealing with observational studies that do not require prior registration. It is possible that we have missed some relevant studies considering the lack of specific indexing terms for commercial driving and the varying terminology of the fitness-to-drive examination.

The available evidence provides rationale for the medical evaluation of commercial drivers but does not clearly dictate what type of examination is needed to determine fitness-to-drive. There is a clear increased prevalence of important health conditions in commercial drivers and there is a correlation of some of these conditions with crashes. Randomised trial design in this setting is challenging and is neither practical nor ethical. In addition, several high-risk and chronic conditions that are relevant to the fitness to drive are under-reported in the literature, including visual impairments, epilepsy, sexually transmitted diseases, the use of illicit drugs and kidney diseases. The implementation of in-motion naturalistic studies and interventional programmes such as *Ticketing Aggressive Cars and Trucks* (TACT) is attainable and carries a solution to assessing and educating on-duty drivers.[7 53 54] Undoubtedly, there is a substantial need to qualify medical personnel to examine and certify drivers for fitness-to-drive. Tailored and occupational health certification courses should not be delayed and currently rank in high priority. The upcoming 2013-14 FMCSA guidelines in the USA may provide some support to such recommendation. There is also a need to establish the importance of individual case-to-case assessment and to avoid advertising one-rule-fits-all, as a physician's discretion remains valuable.

Individual and public education programmes may also be helpful. Commercial drivers-specific assessment training programmes to educate and certify specialised cadres are recommended. The need for further research in assessing diagnostic tests and examining other challenging diagnoses is of importance. Efforts to engage all stakeholders including drivers, employers, unions, physicians and guiding agencies are much needed to achieve these goals.

In conclusion, several medical conditions are highly prevalent in commercial drivers and some of them are associated with increased risk of crashes, thus providing a rationale for requiring medical evaluation of commercial motor vehicle drivers. However, the current evidence is insufficient to recommend diagnostic strategies specific to commercial drivers that can be implemented in current occupational practice, and these strategies are currently derived from studies in the general population.

Author affiliations
[1]Division of Preventive, Occupational and Aerospace Medicine, Mayo Clinic, Rochester, Minnesota, USA
[2]Knowledge and Evaluation Research Unit, Mayo Clinic, Rochester, Minnesota, USA
[3]Department of Internal Medicine, University of Missouri, Columbia, Missouri, USA
[4]Mayo Clinic Libraries, Mayo Clinic, Rochester, Minnesota, USA

Contributors All authors have contributed substantially the body of work and fulfilled the ICMJE guidelines to grant a coauthorship. All authors have given final approval of this version to be published. AMAD participated in study codesigning, data collection and screening, data-analysis and evidence synthesis, and drafting and revising the manuscript. BF participated in study codesigning, data collection and screening, evidence-synthesis and codrafting the manuscript. CTC participated in part of the experts' panel in hypothesis generation, data analysis and revising the manuscript. LWS participated in part of the experts' panel in hypothesis generation and design, data analysis, and revising the manuscript. LJP participated in data acquiring, literature search and screening and revising the manuscript. MHM participated in part of the experts' panel in hypothesis generation and design, data analysis and synthesis and codrafting and revising the manuscript.

Funding This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

REFERENCES

1. FMCSA. Commercial Driver's License Program(CDL/CDLIS). http://www.fmcsa.dot.gov/registration-licensing/cdl/cdl.htm (accessed 5 Feb 2013).
2. FMCSA. Commercial Truck and Bus Driver Facts. 2005 http://www.fmcsa.dot.gov/facts-research/facts-figures/analysis-statistics/driverfacts.htm (accessed 5 Feb 2013).
3. Statistics BoL. National census of fatal occupational injuries in 2012 (preliminary results). U.S. Department of labor; 2012; For release 10:00 a.m. (EDT) Thursday, August 22, 2013: www.bls.gov/news.release/pdf/cfoi.pdf
4. Administration FMCS. Federal motor carrier safety administration: analysis reports. 2008; http://ai.fmcsa.dot.gov/CarrierResearchResults/CarrierResearchContent.asp?p=4
5. Anon. *Cost of large truck- and bus-involved crashes*. Washington, DC: Office of Research and Technology, Federal Motor Carrier Safety Administration, U.S. Department of Transportation, 2001:4.
6. Laberge-Nadeau C, Dionne G, Maag U, *et al*. Medical conditions and the severity of commercial motor vehicle drivers' road accidents. *Accid Anal Prev* 1996;28:43–51.
7. Wiegand DM, Hanowski RJ, McDonald SE. Commercial drivers' health: a naturalistic study of body mass index, fatigue, and involvement in safety-critical events. *Traffic Inj Prev* 2009;10:573–9.
8. Akerstedt T. Consensus statement: fatigue and accidents in transport operations. *J Sleep Res* 2000;9:395.
9. Laberge-Nadeau C, Dionne G, Ekoe JM, *et al*. Impact of diabetes on crash risks of truck-permit holders and commercial drivers. *Diabetes Care* 2000;23:612–7.
10. Young T, Palta M, Dempsey J, *et al*. Burden of sleep apnea: rationale, design, and major findings of the Wisconsin Sleep Cohort study. *Wmj* 2009;108:246–9.
11. Pack AI, Dinges DF, Maislin G. *A study of prevalence of sleep apnea among commercial truck drivers*. Washington, DC: U.S. Department of Transportation, FMCSA, 2002.
12. Hegmann KT, Andersson GBJ, Greenberg MI, *et al*. FMCSA's medical review board: five years of progress in commercial driver medical examinations. *J Occup Environ Med* 2012;54:424–30.
13. Marino M, de Belvis A, Basso D, *et al*. Interventions to evaluate fitness to drive among people with chronic conditions: systematic review of literature. *Accid Anal Prev* 2012.50:377–96.
14. Howard ME, Desai AV, Grunstein RR, *et al*. Sleepiness, sleep-disordered breathing, and accident risk factors in commercial vehicle drivers. *Am J Respir Crit Care Med* 2004;170:1014–21.
15. Tregear S, Reston J, Schoelles K, *et al*. Continuous positive airway pressure reduces risk of motor vehicle crash among drivers with obstructive sleep apnea: systematic review and meta-analysis. *Sleep* 2010;33:1373–80.
16. Wells GA, Shea B, O'Connell D, *et al*. The Newcasete-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analysis. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp (accessed 4 Nov 2012).
17. Whiting PF, Rutjes AW, Westwood ME, *et al*. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* 2011;155:529–36.
18. Husereau D, Drummond M, Petrou S, *et al*. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. *Bmj* 2013;346:f1049.
19. Guide to the methods of technology appraisal. The National Institute for Health and Care Excellence (NICE) http://www.nice.org.uk/aboutnice/howwework/devnicetech/guidetothemethodsofte chnologyappraisal.jsp (accessed 1 Jul 2013).
20. Wong G, Greenhalgh T, Westhorp G, *et al*. RAMESES publication standards: meta-narrative reviews. *BMC Med* 2013;11:20.
21. Sunwoo BY, Jackson N, Maislin G, *et al*. Reliability of a single objective measure in assessing sleepiness. *Sleep* 2012;35:149–58.
22. Sharwood LN, Elkington J, Stevenson M, *et al*. Assessing sleepiness and sleep disorders in Australian long-distance commercial vehicle drivers: self-report versus an 'at home' monitoring device. *Sleep* 2012;35:469–75.
23. Hayano J, Tsukahara T, Watanabe E, *et al*. Accuracy of ECG-based screening for sleep-disordered breathing: a survey of all male workers in a transport company. *Sleep &breathing = Schlaf & Atmung* 2012 Mar 20.
24. Gjerde H, Christophersen AS, Normann PT, *et al*. Analysis of alcohol and drugs in oral fluid from truck drivers in Norway. *Traffic Inj Prev* 2012;13:43–8.
25. Xie W, Chakrabarty S, Levine R, *et al*. Factors associated with obstructive sleep apnea among commercial motor vehicle drivers. *J Occup Environ Med* 2011;53:169–73.
26. Smith B, Phillips BA. Truckers drive their own assessment for obstructive sleep apnea: a collaborative approach to online self-assessment for obstructive sleep apnea. *J Clin Sleep Med* 2011;7:241–5.
27. Morales CR, Wick LC, Hurley S, *et al*. Total sleep time estimated by actigraphy correlates with polysomnography-derived sleep time in commercial drivers. *Am J Respir and Criti Care Med Conf* 2011;183 (1 MeetingAbstracts).
28. Braeckman L, Verpraet R, Van Risseghem M, *et al*. Prevalence and correlates of poor sleep quality and daytime sleepiness in Belgian truck drivers. *Chronobiol Int* 2011;28:126–34.
29. Stanley JJ, Beck A. Prevalence of microsleep in commercial motor vehicle operators during the maintenance of wakefulness test. *Sleep. 2010;Conference:* 24th Annual Meeting of the Associated Professional Sleep Societies, LLC, SLEEP 2010 San Antonio, TX United States. Conference Start: 20100605 Conference End: 20100609. Conference Publication: (var.pagings). 33:A268–A9.
30. Nolte CM, Licata C, McWhirter DY, *et al*. Need of close long term monitoring of commercial drivers with obstructive sleep apnea (OSA). *Sleep. 2010;Conference:* 24th Annual Meeting of the Associated Professional Sleep Societies, LLC, SLEEP 2010 San Antonio, TX United States. Conference Start: 20100605 Conference End: 20100609. Conference Publication: (var.pagings). 33:A140.
31. Doyle J, Severance-Fonte T, Morandi-Matricaria E, *et al*. Improved blood pressure control among school bus drivers with hypertension. *Popul Health Manag* 2010;13:97–103.
32. Riva MM, Marchetti FA, Giupponi V, *et al*. [Health surveillance of truck drivers: it is not just a question of drugs. Description of a one-year experience]. *Med Lav* 2010;101:207–17.
33. Asaoka S, Namba K, Tsuiki S, *et al*. Excessive daytime sleepiness among Japanese public transportation drivers engaged in shiftwork. *J Occup Environ Med* 2010;52:813–8.
34. Morales CR, Wick LC, Soto-Calderon H, *et al*. Prospective occupational screening for obstructive sleep apnea in volunteer commercial drivers. *Am J Respir Crit Care Med Conf* 2010;181(1 MeetingAbstracts).
35. Vennelle M, Engleman HM, Douglas NJ. Sleepiness and sleep-related accidents in commercial bus drivers. *Sleep Breath* 2010;14:39–42.
36. Tanaka F, Nakano H, Sudo N, *et al*. Relationship between the body position-specific apnea-hypopnea index and subjective sleepiness. *Respiration* 2009;78:185–90.
37. Parks P, Durand G, Tsismenakis AJ, *et al*. Screening for obstructive sleep apnea during commercial driver medical examinations. *J Occup Environ Med* 2009;51:275–82.
38. Redelmeier DA, Kenshole AB, Ray JG. Motor vehicle crashes in diabetic patients with tight glycemic control: a population-based case control analysis. *PLoS Med* 2009;6:e1000192.
39. Watkins MR, Talmage JB, Thiese MS, *et al*. Correlation between screening for obstructive sleep apnea using a portable device versus polysomnography testing in a commercial driving population. *J Occup Environ Med* 2009;51:1145–50.
40. Greene BL, Miller JD, Brown TM, *et al*. Economic impact of the BP DownShift Program on blood pressure control among commercial driver license employees. *J Occup Environ Medi* 2009;51:542–53.
41. Lemos LC, Marqueze EC, Sachi F, *et al*. Obstructive sleep apnea syndrome in truck drivers. *J Bras Pneumol* 2009;35:500–6.
42. Martin BC, Church TS, Bonnell R, *et al*. The impact of overweight and obesity on the direct medical costs of truck drivers. *J Occup Environ Med* 2009;51:180–4.
43. Talmage JB, Hudson TB, Hegmann KT, *et al*. Consensus criteria for screening commercial drivers for obstructive sleep apnea: evidence of efficacy. *J Occup Environ Med* 2008;50:324–9.
44. Harshman RS, Richerson GT, Hadker N, *et al*. Impact of a hypertension management/health promotion program on commercial driver's license employees of a self-insured utility company. *J Occup Environ Med* 2008;50:359–65.
45. Zaloshnja E, Miller TR, Hendrie D, *et al*. Employer costs of alcohol-involved injuries. *Am J Ind Med* 2007;50:136–42.

46. Canani SF, John AB, Raymundi MG, *et al*. Prevalence of sleepiness in a group of Brazilian lorry drivers. *Public Health* 2005;119:925–9.
47. Spicer RS, Miller TR. Impact of a workplace peer-focused substance abuse prevention and early intervention program. *Alcoholism* 2005;29:609–11.
48. Gurubhagavatula I, Maislin G, Nkwuo JE, *et al*. Occupational screening for obstructive sleep apnea in commercial drivers. *Am J Respir Crit Care Med* 2004;170:371–6.
49. Dionne G, Desjardins D, Laberge-Nadeau C, *et al*. Medical conditions, risk exposure, and truck drivers' accidents: an analysis with count data regression models. *Accid Anal Prev* 1995;27:295–305.
50. Hartenbaum N, Collop N, Rosen IM, *et al*. Sleep apnea and commercial motor vehicle operators: statement from the joint Task Force of the American College of Chest Physicians, American College of Occupational and Environmental Medicine, and the National Sleep Foundation. *J Occup Environ Med* 2006;48(9 Suppl): S4–37.
51. Gurubhagavatula I, Nkwuo JE, Maislin G, *et al*. Estimated cost of crashes in commercial drivers supports screening and treatment of obstructive sleep apnea. *Accid Anal Prev* 2008;40:104–15.
52. Gjerde H, Christophersen AS, Normann PT, *et al*. Analysis of alcohol and drugs in oral fluid from truck drivers in Norway. *Traffic Inj Prev* 2012;13:43–8.
53. Wiegand DMHR, McDonald SE. Commercial motor vehicle health and fatigue study: final report. 2009; http://scholar.lib.vt.edu/VTTI/reports/Health_and_Fatigue_021109.pdf (accessed 11 Feb 2009).
54. Thomas FD, Blomberg RD, Peck RC, *et al*. Evaluation of a high visibility enforcement project focused on passenger vehicles interacting with commercial vehicles. *J Saf Res* 2008;39:459–68.