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DIABETES AND MOTOR VEHICLE CRASHES: A SYSTEMATIC EVIDENCE-BASED REVIEW AND META-ANALYSIS

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Summary: The primary objective of this systematic review was to address the question, "Are drivers with diabetes mellitus at greater risk for a motor vehicle crash than comparable drivers without the disease?" and secondarily, to address the question, "Are insulin-treated diabetics at higher risk for crash?" Our searches identified 16 articles that addressed these questions. An assessment of study quality of the included studies found them to be in the low-to-moderate range. While attempts were made to control for differences in the characteristics of individuals that may confound the relationship between diabetes and crash risk in all included studies, most failed to control for exposure. A random-effects meta-analysis found that individuals with diabetes have a 19% increased risk for a motor vehicle crash when compared to similar individuals without diabetes. We found no compelling evidence to suggest that insulin-treated individuals are at higher risk for motor vehicle crash than individuals with diabetes not being treated with insulin. We discuss the implications of these findings.

INTRODUCTION

It is widely held that individuals with diabetes, particularly insulin-treated diabetics, are at higher risk of crash while driving. This view stems in large part from the well-known acute disabling effects of the disease (e.g., hypoglycemia), as well as longer term health complications (e.g., retinopathy, cardiovascular complications, and neuropathy). While this view is strongly maintained, the supporting evidence is limited. The primary objective of this systematic review was to address the question, "Are drivers with diabetes mellitus at greater risk for a motor vehicle crash than comparable drivers without the disease?" and secondarily, to address the question, "Are insulin-treated diabetics at higher risk for crash?"

METHODS

This systematic review followed the protocol outlined by Treadwell et al. (2006). Sensitive search strategies, developed and refined by an information specialist, were applied to the following seven electronic databases—Medline, PubMed (pre Medline), EMBASE, PSYCH

Info, CINAHL, TRIS, and the Cochrane Library (through May 28, 2006). Additional hand searches of the published literature (i.e., bibliographies of identified relevant articles) and "gray literature" resources (e.g., Web searches) were also performed. Formal a priori criteria for article retrieval and study inclusion consisted of: (1) English language publications, (2) full-length articles, (3) controlled (case-control or cohort) study design, and (4) enrolled ≥10 patients.

The quality of all included studies was determined using a revised version of the Newcastle/Ottawa Scale (Wells, 2000). Random- and fixed-effects meta-analyses were used to pool data from different studies (Hedges, 1994; Raudenbush, 1994). The Q-statistic and I^2 were used to identify heterogeneity among the studies' results (Higgins, 2003). Sensitivity analyses, aimed at testing the robustness of our findings, included the use of cumulative fixed- and random-effects meta-analysis (Sterne, 1998). Publication bias was tested for using the "trim and fill" method with funnel plots (Duval & Tweedie, 2000).

RESULTS

Evidence Base

Our searches identified a total of 159 potentially relevant articles, of which 16 were found to meet all inclusion criteria (Table 1). These 16 studies (describing unique datasets) addressed the following key questions:

1) What is the risk ratio for a motor vehicle crash among drivers with diabetes compared to drivers without diabetes (13 studies)?
2) Are drivers with diabetes overrepresented among drivers who have had a crash (3 studies)?

In this review we focus on data extracted and combined from the first group of studies and supplement our findings with data from the smaller data set.

Quality of Evidence Base

An assessment of study quality using a validated instrument designed for assessing the quality of case-control and cohort studies found the quality of the included studies to be low-to-moderate (Table 2). Attempts were made by study investigators of all studies to control for differences in the characteristics of individuals that may confound the relationship between diabetes and crash risk. However, the majority of included studies failed to control for exposure.

Generalizability of Evidence Base

One included study (Laberge-Nadeau, 2000) enrolled commercial motor vehicle (CMV) drivers only; the remainder enrolled individuals with a private motor vehicle license. Individuals enrolled in the included studies comprised mixed populations; the majority of studies included individuals with both Type 1 and Type 2 diabetes. Only two studies constricted enrollment to individuals with Type 1 diabetes (Eadington & Frier, 1989; Songer, 1988).

Table 1. Evidence base

Reference	Year	Study Design	Comparison	Driving exposure controlled for?	Primary outcome	Definition of crash	Outcome self-reported?
Studies comparing crash rates among individuals with diabetes and individuals without the disorder (primary data set)							
Cox et al.	2003	CCS	673 individuals with diabetes vs. 363 without diabetes	Yes	Difference in crash rate	Driver in any motor vehicle crash	Yes
Laberge-Nadeau et al.	2000	CCS	4,495 individuals with diabetes vs. 8,958 without diabetes	Yes	Difference in crash rate	CMV driver in any motor vehicle crash	No (provincial records)
de Klerk & Armstrong	1983	CCS	8,623 individuals with diabetes vs. expected rate (Western Australia)	No	Difference in crash rate	Driver in injurious motor vehicle crash	No (hospital records)
Hansotia & Broste	1991	CCS	484 individuals with diabetes vs. 30,420 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	No (State Records)
Stevens et al.	1989	CCS	354 individuals with diabetes vs. 307 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	Yes
Eadington & Frier	1989	CCS	187 individuals with diabetes vs. data obtained from DOT and insurance claims	No	Difference in crash rate	Driver in any motor vehicle crash	Yes
Songer et al.	1988	CCS	127 individuals with diabetes vs. 127 without diabetes	Yes	Difference in crash rate	Driver in any motor vehicle crash	Yes
Davis et al.	1973	CCS	108 individuals with diabetes vs. 1,650,245 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	No (state records)
Ysander	1970	CCS	219 individuals with diabetes vs. 219 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	No (state records)
Campbell & Ellis	1969	CCS	346 individuals with diabetes vs. 346 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	No (provincial records)
McMurray & Crancer	1968	CCS	7,646 individuals with diabetes vs. 1,600,000 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	No (state records)
Ysander	1966	CCS	256 individuals with diabetes vs. 256 without diabetes	No	Difference in crash rate	Driver in injurious motor vehicle crash	No (government records)
Waller	1965	CCS	287 individuals with diabetes vs. 922 without diabetes	No	Difference in crash rate	Driver in any motor vehicle crash	No (state records)
Studies comparing prevalence of diabetes among crashers and non-crashers (secondary data set)							
McGwin et al.	1999	CCS	249 individuals at-fault crash vs. 454 individuals no-crash	Yes	Difference in % of individuals with diabetes	Driver in at-fault crash	Yes (telephone questionnaire)
Gressert & Meyer	1994	CCS	1,400 individuals injurious crash vs. 2,636 individuals no-crash	Yes	Difference in % of individuals with diabetes	Driver in injurious motor vehicle crash	No (provincial records)
Koepsell et al.	1994	CCS	234 individuals injured in crash vs. 446 not involved in crash	Yes	Difference in % of individuals with diabetes	Driver in injurious motor vehicle crash	No (health insurance and police records)

CCS=case-control study

RESULTS

Data from the 13 studies that compared crash risk in drivers with diabetes to comparable drivers without the disease were found to be homogeneous (I^2=13.9%; Q=18.2, *P*=0.1110). This finding suggests that the differences in the design, conduct, and populations used for these studies had little impact on outcome. A fixed effects meta-analysis (Figure 1) showed that individuals with diabetes are at a significantly increased risk for a motor vehicle crash (RR=1.19, 95% CI: 1.08–1.32). In other words, the crash risk for diabetic drivers is 1.19 times greater than the risk for comparable drivers without diabetes. A series of sensitivity analyses found this finding to be robust with none of these analyses overturning the findings of the original analysis. No evidence of publication bias was found.

Table 2. Quality of evidence base

Reference	Year	Quality Scale Used	Quality Score	Quality
Studies comparing crash rates among individuals with diabetes and individuals without the disorder (primary data set)				
Cox et al.	2003	Revised Newcastle-Ottawa Quality Assessment Scale	8.5	Moderate
Laberge-Nadeau et al.	2000	Revised Newcastle-Ottawa Quality Assessment Scale	9.4	Moderate
de Klerk & Armstrong	1983	Revised Newcastle-Ottawa Quality Assessment Scale	6.3	Low
Hansotia & Broste	1991	Revised Newcastle-Ottawa Quality Assessment Scale	5.4	Low
Stevens et al.	1989	Revised Newcastle-Ottawa Quality Assessment Scale	7.0	Low
Eadington & Frier	1989	Revised Newcastle-Ottawa Quality Assessment Scale	7.7	Low
Songer et al.	1988	Revised Newcastle-Ottawa Quality Assessment Scale	7.9	Low
Davis et al.	1973	Revised Newcastle-Ottawa Quality Assessment Scale	5.8	Low
Ysander et al.	1970	Revised Newcastle-Ottawa Quality Assessment Scale	8.1	Moderate
Campbell & Ellis	1969	Revised Newcastle-Ottawa Quality Assessment Scale	6.5	Low
McMurray & Crancer	1968	Revised Newcastle-Ottawa Quality Assessment Scale	4.2	Low
Ysander	1966	Revised Newcastle-Ottawa Quality Assessment Scale	7.1	Low
Waller	1965	Revised Newcastle-Ottawa Quality Assessment Scale	7.1	Low
Studies comparing prevalence of diabetes among crashers and non-crashers (secondary data set)				
McGwin et al.	1999	Revised Newcastle-Ottawa Quality Assessment Scale	10.0	Moderate
Gressert & Meyer	1994	Revised Newcastle-Ottawa Quality Assessment Scale	7.8	Low
Koepsell et al.	1994	Revised Newcastle-Ottawa Quality Assessment Scale	9.4	Moderate

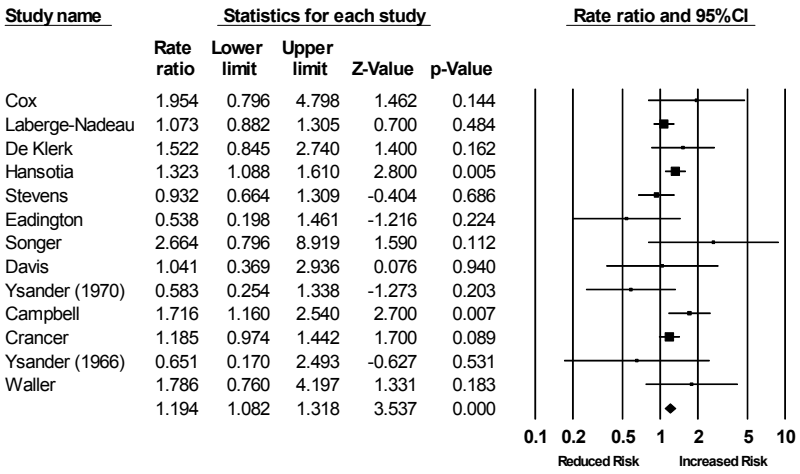

Figure 1. Crash risk in drivers with diabetes relative to drivers without diabetes

Having determined that drivers with diabetes are at an elevated risk for a motor vehicle crash, we next attempted to determine whether there were any specific subgroups of drivers with diabetes who were at greater risk for crash. In particular, we were interested in determining whether insulin-treated diabetic drivers were at a higher risk than individuals treated using either oral hypoglycemic agents or diet alone. The primary risk factor for a crash among individuals with diabetes is traditionally thought to be hypoglycemia. As there is a reasonably large body of literature showing that hypoglycemia occurs more often among individuals treated with insulin than among those treated by pharmacotherapy or diet alone, one might reasonably expect to observe that individuals with insulin-treated diabetes are at higher risk for a motor vehicle crash when compared with individuals who control their diabetes by other means. Five of the 13

included studies provided separate crash risk data for drivers who were insulin-treated (Cox, 2003; Eadington & Frier, 1989; Laberge-Nadeau, 2000; Songer, 1988; Stevens, 1989) allowing us to estimate of the risk ratio associated with this subpopulation of drivers.

Included among the five studies cited above was the study of Laberge-Nadeau et al. (2000). This study specifically assessed crash risk among CMV drivers with diabetes. In so doing, these investigators presented data separately for articulated and straight truck drivers. Making an assumption that the latter two data sets can be considered independent of one another (although sampled from the same database, the two groups consist of a different set of cases and controls), we treated them as if they were two separate studies. Consequently, a total of six data sets containing information on crash risk among drivers with insulin-dependent diabetes were available for analysis. These data were found to be heterogeneous (I^2=68.97%; Q=16.11, *P*=0.0065). Data from a heterogeneous data set cannot be combined in a fixed-effects meta-analysis because such a synthesis is in violation of the model's underlying assumption of homogeneity. Instead, we pooled the available risk-ratio data using random-effects meta-analysis, which allows one to combine heterogeneous data by partitioning the estimated between-studies variance component and adding it to the within-studies variance of each included study (Raudenbush, 1994).

The results of this meta-analysis, which is presented in Figure 2, does not provide evidence supporting the contention that the risk for a motor vehicle crash is significantly higher among individuals with insulin-treated diabetes(RR=1.11, 95% CI: 0.80–1.80, *P*=0.676). Likewise, separate meta-analyses of subsets of data from three studies that compared the odds of having diabetes among a group of individuals who experienced a crash, with the odds of having diabetes among individuals who did not crash, failed to demonstrate that individuals with insulin-treated diabetes represent a population who are at higher risk for crash (Figure 3).

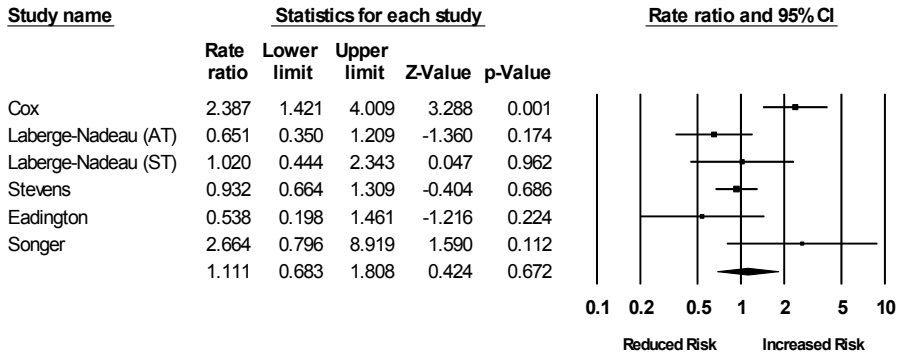

Figure 2. Random effects meta-analysis of crash data from insulin-treated cohorts

DISCUSSION

Drivers with diabetes mellitus are at 19 percent greater risk for a motor vehicle crash than drivers who do not have diabetes. This is important from a public policy perspective because diabetes is a highly prevalent condition with approximately 29 million people or 14.4% of those over 20 years old with diagnosed diabetes, undiagnosed diabetes, or impaired fasting glucose (Centers for Disease Control and Prevention [CDC], 2003).

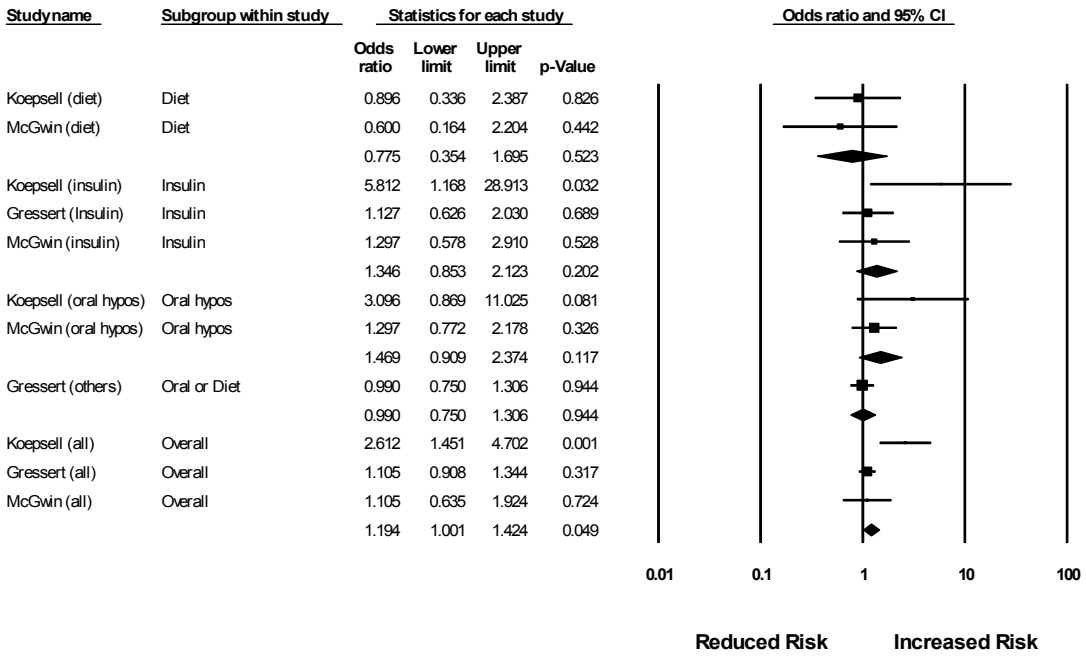

Figure 3. Results of analyses of data from studies of prevalence of diabetes among crashers and non-crashers

Drivers with diabetes are a heterogeneous group with a variety of potential mechanisms that could increase crash risk, in association with both acute and chronic medical complications of diabetes. The critical task is to identify subsets of drivers with diabetes who are at greatest risk for a crash. One such subset that might be suspected of having an increased crash risk is those who are subject to hypoglycemia, a potentially debilitating condition that affects both individuals with Type 1 and Type 2 diabetes. It is believed that insulin treated individuals (all those with Type 1 diabetes and a minority of those with Type 2 diabetes) are at an increased risk for hyperglycemia and hence, crash. Our analyses found no statistically significant evidence to suggest that insulin-treated individuals represent a higher risk subgroup of individuals with diabetes. However, because of the small size of the evidence base (low power) and the possibility that the insulin-treated individuals in the included studies are not representative of all insulin-treated individuals who drive, one cannot construe this finding as providing conclusive evidence that individuals with insulin-treated diabetes are not at greater risk for a crash than non-insulin treated individuals.

The findings of this review underscore the need for additional quality research on driving performance, safety errors, vehicle crashes, and countermeasures in drivers with different complications of diabetes. Relevant research can address driving safety issues related to problems of: 1) vision (e.g., diabetic retinopathy affecting acuity, contrast sensitivity and fields); 2) cognition (e.g., attention, perception, memory and executive function), mood and arousal due to metabolic encephalopathy (e.g., with glucose shifts or renal disease) or cerebrovascular disease; 3) cardiac and peripheral vascular disease; 4) neuropathy (with numbness and weakness affecting control over the pedals); 5) side-effects of medicines; and 6) reduced self-awareness of physiologic and performance impairments caused by these factors.

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