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ORIGINAL ARTICLE

Car accidents in drivers with Parkinson's disease or multiple sclerosis: A Swedish nationwide study

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Abstract

Background and purpose: Parkinson's disease (PD) and multiple sclerosis (MS) can impair driving. However, we lack evidence on car accidents associated with these diseases. The aims of this study were to examine what types of car accident were associated with drivers with PD and MS, compared to individuals with ulcerative colitis (UC; the comparison group), and to evaluate the occurrence of car accidents in relation to years since diagnosis.

Methods: This retrospective nationwide, registry-based study included drivers involved in car accidents between 2010 and 2019, based on the Swedish Traffic Accident Data Acquisition database. Data on pre-existing diagnoses were retrieved retrospectively from the National Patient Registry. Data analyses included group comparisons, time-to-event analysis, and binary logistic regression.

Results: In total, 1491 drivers, including 199 with PD, 385 with MS, and 907 with UC, were registered to have been involved in a car accident. The mean time from diagnosis to the car accident was 5.6 years for PD, 8.0 years for MS, and 9.4 years for UC. Time to car accident since diagnosis differed significantly ($p < 0.001$) among groups (adjusted for age). Drivers with PD had more than twice the odds of a single-car accident than drivers with MS or UC, but no differences were observed between MS and UC.

Conclusions: Drivers with PD were older and experienced the car accident within a shorter timeframe after disease diagnosis. Although several factors may cause a car accident, fitness to drive could be more thoroughly evaluated for patients with PD by physicians, even early after the diagnosis.

KEYWORDS
accidents, automobile driving, multiple sclerosis, Parkinson's disease, traffic

INTRODUCTION

Road traffic deaths and injuries represent a global burden [1]. Despite major advancements in road traffic safety, the prevention of road traffic accidents (RTAs) remains challenging. Parkinson's disease (PD) and multiple sclerosis (MS) are neurological diseases associated with progressive deterioration of cognitive domains and motor functions that are essential for safe driving [2]. Approximately 20,000 people are diagnosed with PD or MS, respectively, in Sweden [3, 4]. Unsafe driving performance was found to be overrepresented in people with PD and MS [5–7]. Among drivers with PD, several explanatory factors have been identified, including motor symptom hindrances, executive dysfunction, divided attention, and drowsiness [2, 8]. In MS, reduced driving ability may be correlated with cognitive deficits, visuospatial inability, and impaired vision [6, 7]. Medical standards for determining fitness to drive are available as

a safety measure in most countries [9]. In Sweden, when a medical condition impairs driving to the extent that a person represents a traffic safety risk, a clinical physician is obligated by law to report the circumstance to the driver licensing authorities [10]. However, determining fitness to drive in a clinical setting is complex, and is not entirely representative [11]. It has been shown that physicians tend to overestimate their patients' driving abilities [12]. Furthermore, a subjective source of error is inevitable, and conclusions in assessments differ among physicians and in different regions [13]. Beyond these aggravating circumstances, the evaluations are also linked to ethical considerations because the ability to drive may be crucial for the patient's everyday life [14, 15].

Some studies have indicated that drivers with PD and MS were involved in RTAs more frequently than the average driver [16, 17]. However, the results have been inconsistent due to a wide range of study methodologies. Drivers with PD were shown to have a 2.63 times higher risk of crashing in simulator studies, but no elevated risk of crashing has been found in self-reports, based on real-life crashes [18]. A 10-year cohort study found that drivers with MS had a crude accident ratio of 3.46 compared to a control group [17]. By contrast, another study in patients with MS but no cognitive deficits did not reveal an elevated crash incidence [19].

It is well established that car accidents are impacted by driver-related factors such as alcohol, drowsiness, risk-taking behavior, distraction, and acute illness among drivers [20] and environmental factors such as weather or road conditions, or time of the day [21]. However, evidence on car accidents associated with chronic and progressive disorders remains limited. Previous studies have mainly focused on establishing crash-risk criteria for individuals with PD and MS. However, all crashes have been treated homogenously, with no consensus on type of car accident or whether the RTAs among individuals with PD and MS differ from those of other road users. The aim of this study, therefore, was to examine what types of car accident were associated with drivers with PD and MS, compared to a comparison group of individuals with ulcerative colitis (UC). A secondary aim was to evaluate the occurrence of car accidents in relation to years since diagnosis.

METHODS

This retrospective study was based on three well-established national registries: the Swedish Traffic Accident Data Acquisition (STRADA) database, the National Patient Registry (NPR), and the Swedish Population Registry. The registers were linked based on the unique Swedish personal identification number.

Study population

Study inclusion criteria for drivers were: involvement in a car accident between 2010 and 2019; age ≥18 years at the time of the accident; and, prior to the accident, having one of the following diagnoses (according to International Classification of Diseases 10th revision [ICD-10]): PD (G20.9) or MS or clinically isolated syndrome (G35.9 or G37.9). A comparison group with UC (K51) was selected because UC is a diagnosis not expected to be associated with an increased risk of RTAs but individuals with UC are nevertheless thoroughly evaluated by clinical physicians, and thus, are indirectly cleared with regard to their fitness to drive. If an individual had been diagnosed with both UC and one of the target diagnoses, they were included in the target diagnosis group. Individuals diagnosed with both MS and PD were excluded. Some individuals were involved in more than one car accident during the study period and, in these cases, only the most recent accident was included in the present analyses.

Data collection

The STRADA data were based on reports of RTAs including car accidents from the police and/or the emergency care hospitals [22]. Since 2003, the Swedish police have been obligated to report all RTAs; these accidents mainly constitute RTAs that involve personal injuries but the reports include details and information about the RTA and the circumstances. The emergency departments voluntarily report, with the patient's consent, any individuals that required healthcare following an RTA. The number of reports from hospitals has increased annually; since 2016, the coverage has been considered to be nationwide.

In STRADA, the descriptive variables include type of car accident, environmental setting (rural/urban), and personal injury severity. The variables included in the present study were selected to demonstrate the type of accident and a compilation of the course of events. Collision events were assigned to one of five subgroups: rear-end; turning/crossing; meeting/overtaking; collision with a vulnerable road user; and other. In accordance with the definition in STRADA, vulnerable road users referred to pedestrians, bicycles, and mopeds. No information on driver at-fault in the collisions was available in STRADA; thus, a single-car accident was seen as a proxy for causality. Trauma severity was indicated by the Injury Severity Score (ISS), derived from the Abbreviated Injury Scale for grading multiple injuries in motor vehicle crashes and predicting mortality [23]. The STRADA coding included the categories “uninjured”, “minor injuries” (ISS 1–3), “moderate injuries” (ISS 4–8), “severe injuries” (ISS 9–75), and “fatal injuries” [24].

The NPR comprises data on all specialized healthcare events among in- and outpatients, according to the ICD-10 codes. In the present study, PD, MS and UC had been diagnosed prior to the accident, and the ICD-10 codes were retrospectively collected for the period in the NPR between 1997 and 2019, including type and date of diagnosis. Statistics Sweden (SCB) provided demographic information from the Swedish Population Registry, namely, the individuals’ sex, age at time of the accident, and country of birth. Data were pseudonymized by the registry manager, who also held the code key. Ethics approval was obtained from the Swedish Ethical Review Authority in 2019 (nr: 2019-04081 and 2020-01725). Informed

consent was not required, in accordance with the Swedish Data Inspection Board's adjudication on registry-based studies.

Statistical analyses

Data were processed using IBM SPSS Statistics v. 28 software (IBM, Armonk, NY, USA). Descriptive statistics were used to evaluate the data. Differences between groups in injury severity were tested using the Kruskal–Wallis test and the pairwise Mann–Whitney *U*-test. The significance level was set to a p value <0.05. The time-to-car-accident data were compared using a log-rank test, and graphically represented with survival curves. Cox proportional hazards regression analyses were performed, adjusting for age at car accident, and are reported with hazard ratios and p values. As a single-car accident was seen as a proxy for causality, binary logistic regression analyses were made to determine whether the diagnosis affected the risk of a single-car accident. First, univariable logistic regression was performed on each independent variable, and variables were acceptable for inclusion in the multivariable model if the p value was ≤ 0.25. In the final multivariable analysis, the significance level was set at $p \leq 0.05$. The final model was tested for goodness-of-fit with the Hosmer-Lemeshow test and for accuracy with Cox and Snell's R^2 and Nagelkerke's R^2 tests. Additionally, model performance was evaluated with the receiver-operating characteristic curve. An area under the curve >0.5 was considered acceptable.

RESULTS

In total, 1491 drivers with PD, MS and UC (comparison group) were involved in a registered car accident between 2010 and 2019 (Figure 1). Of these, 199 had PD, 385 had MS, and 907 had UC. Drivers with PD had a higher mean age (69 years) at the time of the accident (Table 1). Overall, men were overrepresented, yet proportionally more women than men were found in the MS group.

The drivers with PD were diagnosed at a mean of 5.6 years prior to the car accident, whereas those in the MS group were diagnosed at 8.0 years and in the comparison group 9.4 years prior the accident (Table 1). The trends in accidents over time differed significantly ($p < 0.001$) between groups (Figure 2a). Drivers with PD were at risk of a car accident after a shorter disease duration, compared to the other groups. Within 5 years from diagnosis, car accidents had occurred in 51% of the PD group, compared to 31% and 25%, respectively, in the MS and the comparison groups. When adjusted for age, the differences between the groups were reduced, but remained significant (Figure 2b).

The most common type of car accidents differed across the groups (Figure 3). In the PD group, a single-car accident (33.7%) was most common, and in people with MS, the majority of accidents were rear-end collisions (33.5%), followed by single-car accidents (22.6%), similar to the comparison group. The distribution of environmental (urban or rural) settings of the car accidents was similar across the groups (Table 1).

Similar proportions of patients were confirmed to have received healthcare or evaluations at a hospital due to the car accident (41–43%). Minor or no injury was the most common type of injury after the car accident in all groups (Table 1). Moderate or major injuries occurred in 11.5% of the accidents in the PD group, 7% in the MS group, and 5.3% in the comparison group. The PD group exhibited worse injuries than the reference group (p = 0.001), based on the proportions with ISS ≥4, compared to ISS 1–3. Overall, the number of fatalities was low.

A multivariable binary logistic regression was used to investigate contributing factors for involvement in a single-car accident, and diagnosis of PD was significantly associated with the occurrence of single-car accidents (Table 2). Drivers with PD had approximately twice the odds of experiencing a single-car accident (odds ratio [OR] 2.13, 95% confidence interval [CI] 1.45–3.14), compared to the comparison group. Drivers in the 36–55 years age group were significantly less likely to be in a single-car accident (OR 0.51, 95% CI 0.37–0.70), compared to drivers aged 18–35 years.

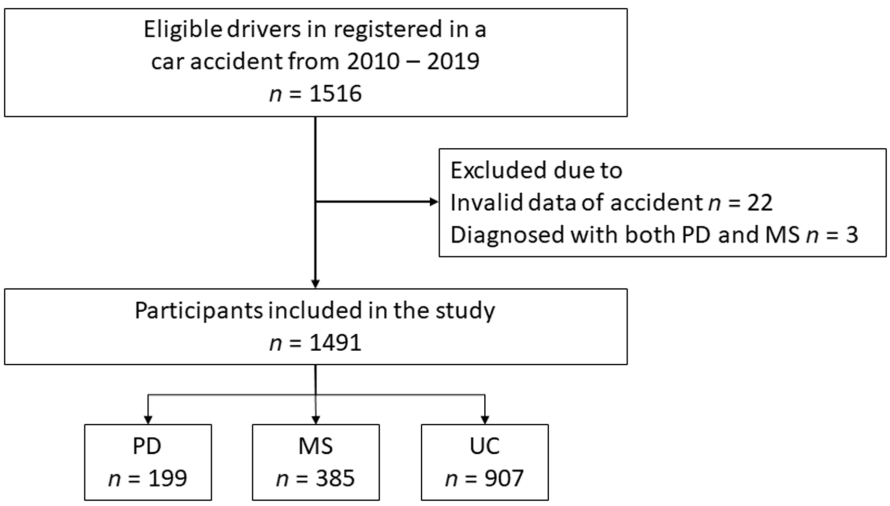


FIGURE 1 Flow chart of the study inclusion process. MS, multiple sclerosis; PD, Parkinson's disease; UC, ulcerative colitis.

TABLE 1 Characteristics of the study population.

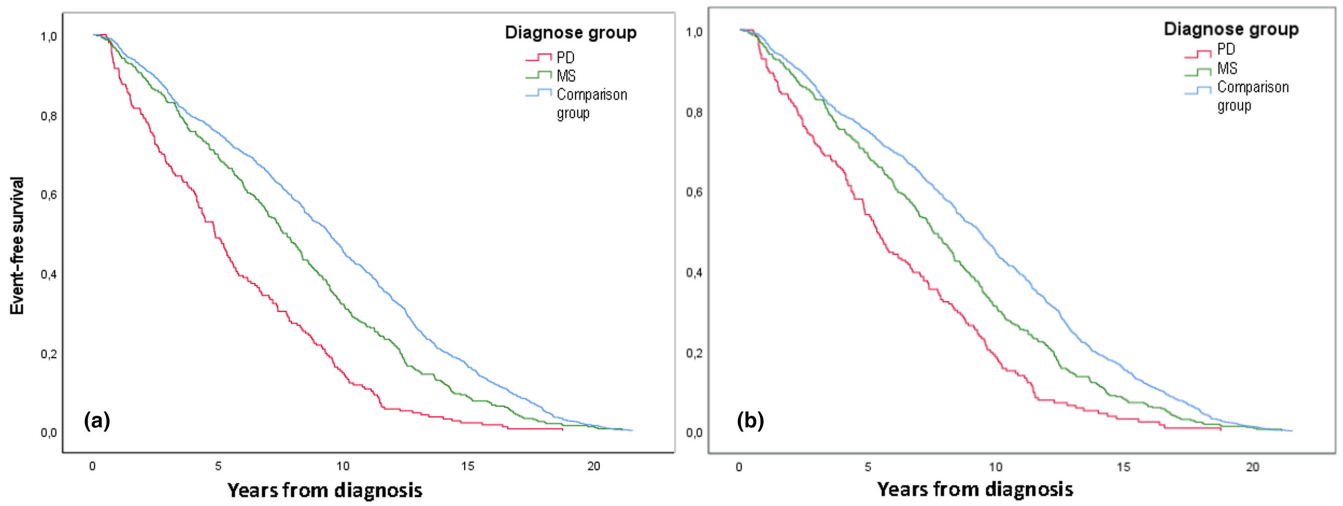
Variable	PD *n* = 199	MS *n* = 385	Comparison group *n* = 907
Driver characteristics			
Age, years, mean (min–max)	69 (30–92)	46 (19–85)	47 (18–90)
Age group, *n* (%)			
18–35 years	1 (0.5)	82 (21.3)	264 (29.1)
36–55 years	22 (11.1)	231 (60.0)	374 (41.4)
56–74 years	117 (58.8)	63 (16.4)	226 (24.9)
≥ 75 years	59 (29.6)	9 (2.3)	42 (4.6)
Sex, *n* (%)			
Male	164 (82.4)	155 (40.3)	567 (62.5)
Female	35 (17.6)	230 (59.7)	340 (37.5)
Country of birth, *n* (%)			
Sweden	166 (83.4)	305 (79.2)	622 (68.4)
Abroad	20 (10.1)	52 (13.5)	124 (13.8)
Unknown	13 (6.5)	28 (7.3)	161 (17.8)
Years since diagnosis, mean (min–max)	5.6 (0.5–18.7)	8.0 (0.1–21.1)	9.4 (0.2–21.5)
Crash characteristics			
Crash type, *n* (%)			
Single-car	67 (33.7)	87 (22.6)	179 (19.7)
Multi-car collision	128 (66.3)	292 (77.4)	703 (80.3)
Environmental setting, *n* (%)			
Urban	84 (42.2)	176 (45.7)	415 (45.8)
Rural	107 (53.8)	180 (46.8)	456 (50.2)
Unknown	8 (4.0)	29 (7.5)	36 (4.0)
Confirmed hospital evaluation, *n* (%)	83 (41.7)	165 (42.9)	390 (43.0)
Injury severity, *n* (%)			
Uninjured	81 (40.7)	142 (36.9)	333 (36.7)
Minor (ISS 1–3)	85 (42.8)	202 (52.5)	493 (54.4)
Moderate (ISS 4–8)	18 (9.0)	23 (6.0)	36 (4.0)
Major (ISS ≥9)	5 (2.5)	4 (1.0)	12 (1.3)
Fatal	2 (1.0)	4[a] (1.0)	8 (0.9)
Unknown	8 (4.0)	10 (2.6)	25 (2.7)

Abbreviations: ISS, injury severity score; MS, multiple sclerosis; PD, Parkinson's disease.

[a]Two cases are based on unofficial statistics. Unofficial statistics include death that not with certainty was a direct consequence of the car accident. Death recoded in unofficial statistics could be attributable to acute illness, suicide, crime or after >30 days of hospitalization after the accident.

DISCUSSION

The results of this study showed that car accidents among drivers with PD differed significantly from those among drivers with MS or UC with regard to the type of accident and the time interval between the accident and the diagnosis date. Drivers with PD had approximately twice the odds of experiencing a single-car accident compared to the other groups. A previous study on drivers with conditions known to contribute to excessive daytime sleepiness showed that drivers with PD and/or epilepsy had a 2.5 higher probability of involvement in a single-car accident [25]. The high occurrence of single-car accidents among drivers with PD may highlight two concerns. First, no road users were involved in the accident other than the drivers included in the present study. Without identifying the specific cause, this finding indicates that the driver with PD may have been responsible for the accident.



Diagnose group	HR	95% CI	*p*-value
Crude			
Reference group	Reference		
PD	2.37	2.02-2.77	**<0.001**
MS	1.33	1.18-1.50	**<0.001**

Abbreviations: CI=confidence interval.

Diagnose group	HR	95% CI	*p*-value
Adjusted*			
Reference group	Reference		
PD	2.02	1.70-2.41	**<0.001**
MS	1.33	1.18-1.49	**<0.001**

*Adjusted for age at diagnosis.
Abbreviations: CI=confidence interval.

FIGURE 2 Time from diagnosis to car accident. (a) Kaplan–Meier curves showing the time to car accident for the different disease groups. (b) Age-adjusted Cox regression model results showing the time to car accident after adjusting for participant age at the time of the accident. HR, hazard ratio; MS, multiple sclerosis; PD, Parkinson's disease.

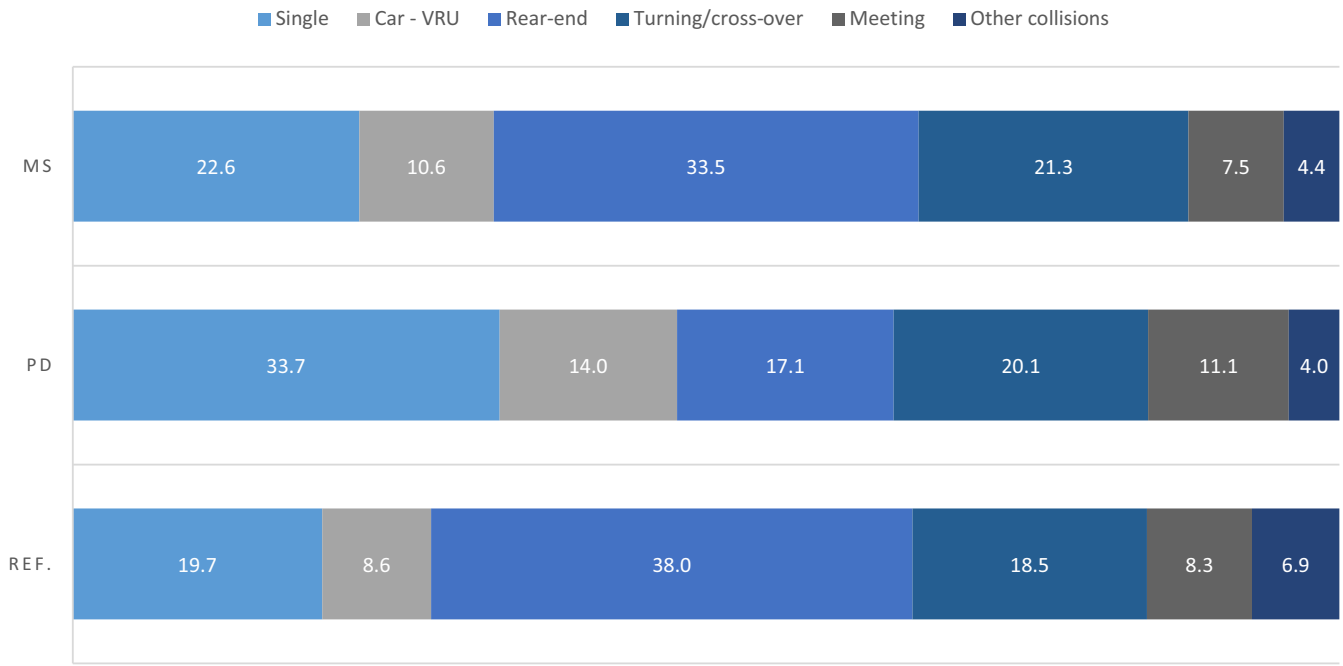


FIGURE 3 Distributions of type of accidents in the Parkinson's disease (PD), multiple sclerosis (MS) and comparison groups. VRU, vulnerable road user (i.e., pedestrians, bicycles, or mopeds).

There are many potentially contributing factors that can cause an accident, such as weather or traffic intensity [20, 21], nevertheless, this finding is alarming. Second, drivers with PD may not be able to rapidly adapt their driving to road conditions, errors from other road users, or other precipitating events. The clinical picture of PD has shown that divided attention, impaired reaction times, and prolonged movement times were not unusual PD symptoms, and these factors were predictors of failing an on-road test [5]. Moreover, in another previous study, single-vehicle accidents were precipitated by a lack of recognition of potential hazards and occurred more frequently in relaxed environments that required fewer driving maneuvers [26].

TABLE 2 Univariable and multivariable binary logistic regression results show predictors of involvement in a single-car accident.

	Univariable		Multivariable	
Variable	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**
Diagnosis		**<0.001**		**<0.001**
UC (comparison group)	Reference		Reference	
PD	2.06 (1.48–2.89)	**<0.001**	2.13 (1.45–3.14)	**<0.001**
MS	1.19 (0.89–1.59)	0.245	1.31 (0.97–1.76)	0.075
Years since diagnosis	0.99 (0.96–1.01)	0.266		
Age group		**<0.001**		**<0.001**
18–35 years	Reference		Reference	
36–55 years	0.54 (0.39–0.74)	**<0.001**	0.51 (0.37–0.70)	**<0.001**
56–74 years	0.96 (0.70–1.33)	0.820	0.78 (0.55–1.10)	0.158
≥75 years	0.88 (0.53–1.44)	0.598	0.59 (0.34–1.03)	0.063
Sex				
Female	Reference			
Male	0.99 (0.77–1.26)	0.911		

Note: Model performance: Hosmer and Lemeshow test = 0.798; Cox and Snell's R^2 = 0.024; Nagelkerke's R^2 = 0.036; area under the receiver-operating characteristics curve = 0.61. Bold indicates statistically significant.

Abbreviations: CI, confidence interval; MS, multiple sclerosis; OR, odds ratio; PD. Parkinson's disease; UC, ulcerative colitis.

A high percentage of fatal and moderately/severe injuries was found among drivers with PD. On average, drivers with PD were older at the time of the accident compared to drivers without PD, and older age with increased fragility are well-known risk factors for severe injuries [27, 28].

More than half of the drivers with PD had experienced the car accident less than 5 years since the diagnosis, significantly earlier than the other groups, even when adjusted for age. Difficulties in motor and/or cognitive function are often present at the time of the PD diagnosis [29, 30]. The present findings suggest that the ability to drive safely might be impaired even in the early stages of PD. Moreover, we observed a decline in accidents at later time points after the diagnosis, suggesting that, as the disease progressed, individuals with PD may have learnt self-regulation or had stopped driving [31, 32]. Alternatively, the present study period may have been insufficient to capture later events.

The car accidents did not differ considerably between the drivers with MS and the comparison group. This finding might be attributable to heterogeneity among drivers with MS, with a wide range of symptoms and the majority of individuals with MS experiencing a relapsing-remitting course [33]; few individuals with MS have an uninterrupted, progressive disease course from the beginning, therefore, our follow-up period might have been too short to address events that might have occurred during a secondary progressive state. Furthermore, it has been shown that individuals with MS may self-regulate their driving, according to the progress of the disease [34].

Previous studies that aimed to establish the prevalence and risk of RTAs among individuals with PD or MS mainly used questionnaires, prospective cohorts, or driving simulator tests [16, 18]. In the present study comprising a national cohort, the total numbers of car accidents in the PD and MS groups may appear low compared to the comparison group. However, we lacked information on the exact prevalence of PD, MS and UC in the general population during the study period, the number of driver's license holders, and the number of active drivers in the disease populations. Thus, it was not possible to draw any conclusions about the percentage of accidents relative to the size of the population at risk. However, it is important to bear in mind that both PD and MS are disorders that require driving restraint. The car accidents found and analyzed in the present study do not imply unsafe driving on an individual level, due to the large number of factors involved in causing a car accident. Nonetheless, our data were based on real-life traffic settings, where various driving abilities were more or less required. Consequently, the differences between groups indicated that drivers with PD may have contributed to causing the car accidents. However, more research is needed, including on potential risk factors such as medications or cognitive function.

For clinical physicians, the conceptual premise of evaluating patients' driving ability is loaded with ethical considerations [14, 15]. The challenges the patient faces in the transition to ceasing driving may give rise to conflict and loss of trust between the patient and the medical doctor [35]. As a result, together with the fear of reporting without certainty, many clinical physicians might avoid making a decision regarding the patient's fitness to drive. Improved guidelines, more education, and support are required.

In conclusion, among individuals with MS and PD, car accidents differed in several ways. Individuals with PD were older and experienced their car accident within shorter timeframes after a diagnosis compared to individuals with MS. Moreover, the odds of being

involved in single-car accident were higher in drivers with PD than in drivers with MS or in the comparison group. Although many factors are involved in a car accident, the driving abilities of patients with PD could be more thoroughly evaluated by clinical physicians, even early after the diagnosis.

AUTHOR CONTRIBUTIONS

All authors were involved in the conceptualization of the study. Helena Selander and Hanna C. Persson were involved in the data collection and acquired the funding for the study. Linnea Anjemark performed data management, formal analysis, and was responsible for the figures and performed the main literature searches. All authors were involved in data interpretation and manuscript writing and have read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are not available from the authors, except the data presented, which were approved by the Ethical Review Board. Our analyses were based on data from different registries (registry managers: Swedish Transport Administration, National Board of Health and Welfare, and the Social Insurance Agency of Sweden), and those data are available upon reasonable request to each of the registry managers.

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