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SICKNESS ABSENCE, DISABILITY PENSION, AND PERMANENT MEDICAL IMPAIRMENT, AMONG CAR OCCUPANTS INJURED IN A CRASH

THESIS FOR DOCTORAL DEGREE (Ph.D.)

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ABSTRACT

Background

Health loss in the road transport system is a major global public health problem, with approximately 1.35 million people killed annually, and it is also the fifth leading cause of overall burden of disease. Based on the Vision Zero, fatal or serious injuries within the road transport system are unacceptable. This thesis presents a new perspective of health loss after a car crash by examining the short- and long-term situation among people injured, in terms of sickness absence (SA) and disability pension (DP) and relating them to permanent medical impairment (PMI), the definition of serious injury used in Sweden. The overall aim was to generate knowledge about SA, DP, and PMI among injured passenger car occupants of working age.

Methods

Four register-based studies (I-IV) were conducted, based on microdata linked from four Swedish nationwide registers. In studies II-IV also data from the Folksam Insurance Group was used, including reported car crashes. Study I was cross-sectional and included injured car occupants who had inpatient or specialized outpatient healthcare after a crash in 2010 (N=9427). Studies II-IV were prospective cohort studies of individuals reporting injuries from car crashes to Folksam. Study II included 64,007 car occupants injured in 2001-2013. Study III (N=63,358) and IV (N=14,363 front-seat car occupants with symptoms of whiplash associated disorders (WAD) after rear-end crashes) used sub cohorts of Study II, and calculated net days of SA/DP per year in relation to the crash. Associations were assessed with multivariable logistic regression (I-IV). SA spells ≤14 days were not included.

Results

Among the inpatient and specialized outpatient healthcare patients injured in a car crash, 9% were already on SA/DP at the crash, while 10% had a new SA spell in direct relation to the crash. Among individuals reporting injury to Folksam, 2% had a new DP two years after the crash, 8% had injuries resulting in PMI. Among occupants with long-term WAD (symptoms >4 weeks) and occupants with injuries resulting in PMI, the mean annual net days of SA/DP increased substantially after the crash. In these groups, the number of SA/DP days remained high for several years after the crash. A distinct trend showed that the proportion granted DP increased with increasing PMI grade. The safety level of the car had significant importance for the future SA/DP situation and if the injury resulted in PMI. Occupants in older cars were more likely to have >180 days SA/DP in year two and four following the crash and were more likely to have an injury resulting in PMI, by up to three times, when compared to occupants of newer cars. Occupants of cars rated 2-3 stars by Euro NCAP were 40% more likely to have >180 days SA/DP in year two, compared to those in cars rated 4-5 stars. Furthermore, women reporting WAD after a rear-end crash in cars fitted with whiplash protection systems were less likely to have PMI and long-term WAD compared only to injured women in older cars without such protection system. Men injured in cars with whiplash protection systems were less likely to have long-term WAD and PMI compared to injured men in both older and newer cars without such protection system. They were also less likely to have >90 days SA/DP in year two, compared to men in older cars without systems. In general future SA and DP were also more common among those with previous SA.

Conclusions

Injuries resulting in PMI reflected the future situation of those injured in a crash in terms of higher SA/DP after the crash. Associations were found between car safety and SA/DP following the crash. The results indicate that the whiplash protection systems benefitted women to less extent than men. Previous SA/DP needs to be taken into consideration when studying SA/DP following a crash.

SVENSK SAMMANFATTNING

Bakgrund: Hälsoförluster i vägtransportsystemet är ett stort folkhälsoproblem. Globalt omkommer varje år 1,35 miljoner personer på grund av trafikolyckor. Utifrån Nollvisionen är allvarliga och dödliga personskador i vägtransportsystemet oacceptabla. I avhandlingen presenteras nya perspektiv på hälsoförlust efter bilolycka genom att undersöka situationen både kort- och långsiktigt för skadade personer. Sjukskrivning (SA) och sjuk- och aktivitetsersättning (DP) studeras och sätts i relation till det i Sverige använda måttet på allvarlig skada: medicinsk invaliditet (PMI). Syftet med avhandlingen var att generera fördjupad kunskap om SA, DP och PMI bland personer i arbetsför ålder som skadats i en personbilsolycka, som förare eller passagerare.

Metod: Fyra registerbaserade studier (I-IV) genomfördes, baserade på länkad mikrodata från fyra svenska nationella register och i studie II-IV även data från Folksam, gällande rapporterade bilolyckor. Studie I var en tvärsnittsstudie som inkluderade 9427 personer som år 2010 fick sluten- och/eller specialiserad öppenvård efter en bilolycka. Studie II-IV var prospektiva kohortstudier med dem som rapporterat personskador efter en bilolycka till Folksam. Studie II inkluderade 64.007 personer som skadats under åren 2001-2013. I Studie III följdes de 63.358 i Studie II som inte haft en ny sådan olycka inom fyra år. I studie IV ingick de 14.363 av personerna i Studie II som varit förare eller framsätespassagerare och anmält en whiplashskada (WAD) efter att bilen blivit påkörd bakifrån och som inte haft en ny olycka inom tre år. Antal nettodagar med SA/DP beräknades årsvis från olycksdagen. Samband beräknades med multivariabla logistiska regressionsanalyser.

Resultat: Bland de som fått sluten- eller specialiserad öppenvård efter en bilolycka, hade 9% redan pågående SA/DP vid olyckan medan 10% påbörjade ett nytt SA-fall i direkt anslutning till olyckan. Bland dem som rapporterade en personskada till Folksam, så hade 2% fått en ny DP två år efter olyckan och totalt resulterade 8% av personskadorna i PMI. Generellt var SA/DP även flera år efter olyckan vanligare bland dem som redan innan olyckan hade SA. Medelantalet SA/DP dagar ökade betydligt efter olyckan bland dem vars personskada resulterade i PMI, liksom bland dem med långvarig WAD (>4 veckor). I dessa grupper förblev antalet SA/DP dagar högt flera år efter olyckan. En tydlig trend visade att andelen med ny DP ökade med högre grad av PMI.

Bilens säkerhetsnivå hade en stor betydelse för både framtida SA/DP och PMI. De personer som skadades i bilar som introducerats innan 2004 hade två till tre gånger högre risk för SA/DP >180 dagar både år två och fyra efter olyckan, jämfört med dem som skadades i nyare bilar. De som skadats i äldre bilar hade också högre risk att personskadan resulterade i PMI. Personer som skadades i bilar med lägre säkerhetsbetyg (2-3 stjärnor) i konsumentkrocktestet Euro NCAP hade 40% högre risk för SA/DP >180 dagar år fyra, jämfört med dem som skadades i säkrare bilar (4-5 stjärnor). Bland både kvinnor och män som rapporterat WAD efter en påkörning bakifrån, hade de som skadades i bilar med whiplashskydd lägre risk för långvariga symptom samt WAD resulterande i PMI, jämfört med dem som skadades i en äldre bil utan whiplashskydd. Bland männen i nya bilar med whiplashskydd var det också mindre risk för att ha långvariga symptom och WAD resulterande i PMI, jämfört med dem i nya bilar utan whiplashskydd. De hade även lägre risk att ha SA/DP >90 dagar år två, jämfört med dem i äldre bilar utan sådana skydd.

Slutsatser och rekommendationer: Det finns ett stort samband mellan en bils säkerhetsnivå och framtida SA/DP och PMI bland de skadade. Ytterligare förbättringar av den övergripande säkerhetsnivån i bilflottan behövs. De studerade systemen som avses minska whiplashskador verkar i mindre utsträckning gynna kvinnor, varför förbättringar av dessa system behövs. I studier av SA/DP efter en olycka bör hänsyn även tas till förekomst av SA/DP redan innan olyckan.

LIST OF SCIENTIFIC STUDIES

I. Elrud, R., Stigson, H., Ohlin, M., Alexanderson, K., Kjeldgård, L., Friberg, E. Sickness Absence among Passenger Car Occupants following a Crash. International Research Council on Biomechanics of Injury (IRCOBI) Conference proceedings 2017; IRC-17-18:79-90.

II. Elrud, R., Friberg, E., Alexanderson, K., Stigson, H. Sickness absence, disability pension and permanent medical impairment among 64 000 injured car occupants of working ages: A two-year prospective cohort study. Accident; analysis and prevention. 2019;127:35-41.

III. Elrud, R., Friberg, E., Alexanderson, K., Stigson, H. Sickness absence and disability pension among injured car occupants, and associations with injury and car safety factors: a prospective cohort (In manuscript).

IV. Elrud, R., Friberg, E., Alexanderson, K., Stigson, H. Long-term whiplash-associated disorders, sickness absence, and disability pension following rear-end car crashes, and associations with whiplash protection systems: a prospective cohort study (In manuscript).

CONTENTS

LIST OF ABBREVIATIONS AND TERMS USED

AIS	Abbreviated Injury Scale
Car	The term car is here used for passenger cars, defined as: Supermini, Small Family Car, Large Family Car, Executive Car, MPV, and SUV
CI	Confidence Interval
DP	Disability pension
ESC	Electronic Stability Control
Euro NCAP	The European New Car Assessment Programme
ICD	International Classification of Diseases
IRTAD	The International Traffic Safety Data and Analysis Group
LISA	The Longitudinal Integration Database for Health Insurance and Labour Market Studies (kept by Statistics Sweden)
MAIS	Maximum Abbreviated Injury Scale
MAIS 2+	Maximum Abbreviated Injury Scale score of two or greater
MAIS 3+	Maximum Abbreviated Injury Scale score of three or greater
MiDAS	The MicroData for Analysis of the Social Insurance database (kept by The Swedish Social Insurance Agency)
MY	Model Year
MYI	Model Year of Introduction
NPR	The National Patient Register (kept by the National Board of Health and Welfare)
OECD	The Organisation for Economic Co-operation and Development
OR	Odds Ratio
PMI	Permanent Medical impairment
RPMI	Risk of Permanent Medical Impairment
RPMI ≥1%	The definition of a serious injury by the Swedish Road Transport Administration, defined as an injury resulting in a permanent medical impairment of 1% or more
RPMI ≥10%	The definition of a very serious injury by the Swedish Road Transport Administration, defined as an injury resulting in a permanent medical impairment of 10% or more
SA	Sickness absence
SDG	Sustainable Development Goals
STRADA	Swedish Traffic Accident Data Acquisition
T_0	The date of the car crash
WAD	Whiplash-associated disorder
Y_x	The respective year before or after T0

1 BACKGROUND

Road traffic injuries are a major public health problem. The World Health Organization estimated road traffic crashes to be the cause of 1.35 million deaths in 2016[1]. The number of individuals being non-fatally injured globally, has been estimated at 50 million per year[2]. With an increasing number of vehicles on the roads around the world, primarily due to increased motorization, road traffic accidents are predicted to be the seventh leading cause of burden of disease in 2030[3]. Road traffic injuries were the fifth leading cause of disability adjusted life years globally in 2016[4]. Nearly 90% of disability adjusted life years lost due to road injuries have been estimated to occur in low- and middle-income countries, although the macroeconomic burden in terms of effect on gross domestic product is higher in high-income countries, due to higher productivity and healthcare costs[5]. Furthermore, road traffic injuries affect individuals of working ages to a high extent. Half of all casualties worldwide are among people aged 15-44 years, while in high-income countries, the mortality rate is the highest for the age group of 15-29 years old[2].

Interventions to prevent road traffic injuries have been undertaken, however, mainly in high-income countries. These have in many cases been successful in decreasing the number of road traffic casualties[1]. In many countries in Western Europe, the number of deaths have declined since the beginning of the 1970s[6]. Between 1991 and 2017, the number of fatalities in road traffic per 100,000 inhabitants declined from 16.1 to 4.9 in the European Union, and from 8.7 to 2.5 in Sweden (Figure 1)[7]. The main part of the reduction in Sweden is due to fewer fatalities among car occupants[8]. In the early 2000s, around 400 car occupants were fatally injured per year, this number had decreased to 137 in 2019[9, 10]. As the number of deaths decreases, the focus among stakeholders and decision makers has shifted to be wider at a policy level; towards preventing injuries. This has been reflected in road traffic safety policy. However, the number of non-fatal injuries has not seen a similar decrease as fatalities in most countries[11, 12].

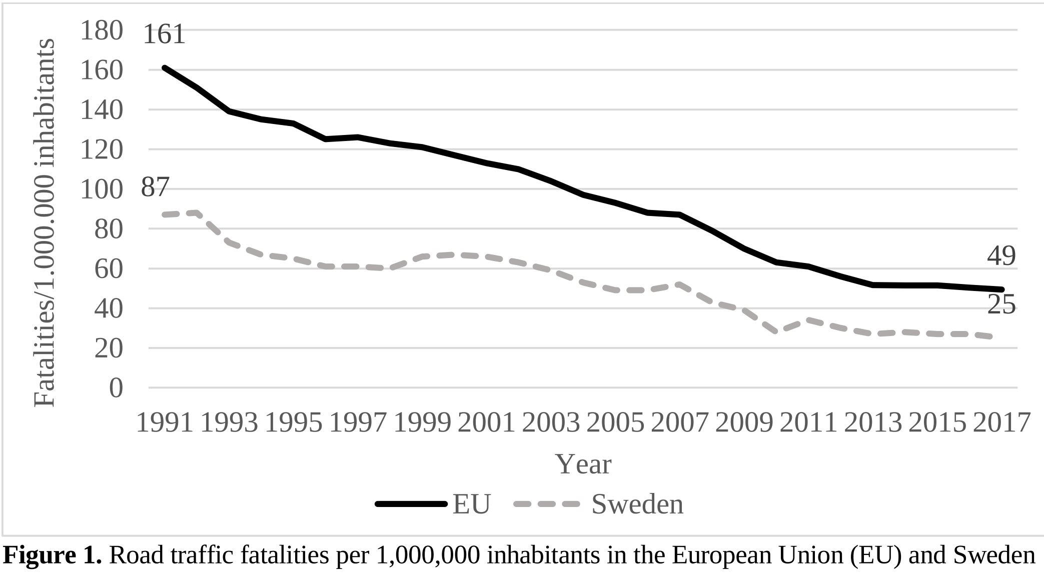

Figure 1. Road traffic fatalities per 1,000,000 inhabitants in the European Union (EU) and Sweden 1991-2017. Source: Community database on Accidents on the Roads in Europe (CARE)[7].

1.1 A SUSTAINABLE ROAD TRANSPORT SYSTEM

The need to address the problem of road traffic fatalities and injuries has been recognized nationally and internationally. In 2010, the United Nations General Assembly proclaimed a decade of action for road safety during 2011-2020, with the overall goal to stop the increase in number of fatalities and reduce the expected numbers[13]. Road safety was in 2015 included in the 2030 Agenda for sustainable development[14]. Two of the goals explicitly targets road safety; Target 3.6 is to reduce the number of fatalities and injuries from road traffic accidents by half, by 2020 and Target 11.2 is to provide access to transport systems which are safe, affordable, accessible and sustainable for everyone. This target emphasizes specifically the attention to persons with disabilities, children, women, and older persons[14]. The European Union has already updated the 2020 goals, and set a target to halve the number of serious injuries from 2020 to 2030[15]. In Sweden, the national goal will also be updated. The current goal set in 2009 by the Parliament was to reduce the number of fatalities by half, and the number of serious injuries by 25% between 2007 and 2020[12].

In the light of the progress made with the Decade of Action for Road Safety, new recommendations for the coming decade have been proposed in the context of the 3rd Global Ministerial Conference on Road Safety 2020[16]. The proposal for a new goal is a 50% reduction of fatalities and serious injuries between 2020 and 2030. This should be achieved by integrating road safety among the other goals of the Agenda 2030[16]. In the Agenda 2030, the Sustainable Development Goals (SDG) are described as “integrated and indivisible”[14]. Target 3.6 and 11.2 have also been found to have interactions with other SDGs. Better health, due to reduced injuries, will e.g., support people to enter the work force, which will also be beneficial to employment and the economy (Goal 8). Target 3.6 and 11.2 interact also with each other. By providing a safe transport system, the number of fatalities and injuries from road traffic accidents will be reduced. There are many other possible interactions, e.g., with gender equality and air quality.

The 2030 goal should also be achieved by an adoption of Safe System principles. With the Safe System approach, the road transport system is designed to minimize health loss due to crashes, by accommodating for human error. The road transport system should be adapted to the limitations of the road user and by adapting the road and vehicle either to be more tolerant of human error in a passive sense (e.g. mid barriers, roundabouts) or to actively take over if an error is detected (e.g. an advanced safety system such as an autonomous emergency braking system)[17, 18].

1.1.1 Vision Zero

The successful development in Sweden during the last two decades, has been achieved by a systematic work based on the road traffic safety policy Vision Zero. The policy was adopted by the Swedish parliament in 1997[19-21]. It is based on Safe System principles and aims toward no fatalities or serious injuries in the road transport system. The long-term goal of Vision Zero is that no unacceptable health loss, defined as fatal or serious injuries, should occur within the road transport system. Serious injury has been described as “those injuries where the victim does not physically recover within a certain period of time”[22]. To reflect this, the Swedish government has, therefore, since 2008 extended the definition of serious injuries to include long-term consequences of injuries. This is defined as injuries with a Risk of Permanent Medical Impairment (RPMI) of ≥1%[23]. With the Safe System approach of Vision Zero, the road transport system should be designed to not expose the road user to biomechanical loading exceeding the human tolerance[24]. Hence, the parameters that set the limits in the system should be the physical and mental limitations of the human being. Since the road transport system should be available to everyone, it is important that the system is designed with respect to the injury tolerance limits of the most vulnerable groups[25]. Adapting the road transport system entails preventing shortcomings in the design and operation of the road and the vehicle as well as handle human error[24]. In this way, the responsibility for road safety is shared between system provider, i.e., actors influencing the design and function of the road transport system, and the road users. However, the ultimate responsibility to prevent unacceptable health loss for the entire system is with the providers. Should the road user fail to take their responsibility to follow regulations and show judgment and consideration, measures must have been taken by the system provider to prevent unacceptable health losses[24]. The vision of a road transport system free from health losses, has been the guiding principle for road safety in Sweden and the approach has arguably been successful. The concept of Vision Zero has, since it was introduced in Sweden, also been adopted by several other countries and local authorities[26-33].

Although the number of car occupants who are killed or injured in crashes have decreased over the last decade in Sweden, car occupants constituted 31% of all those prognosticated being seriously injured, and 38% of those very seriously injured (RPMI ≥10%), in 2018[34]. The efforts made have also been effective in reducing some injury types more than others. As shown in Figure 2, injuries to the head, thorax and lower extremity resulting in permanent medical impairment (PMI) have been reduced substantially over the last 40 years, while other injury types such as cervical and lumbar spine injuries have not seen a similar reduction[35].

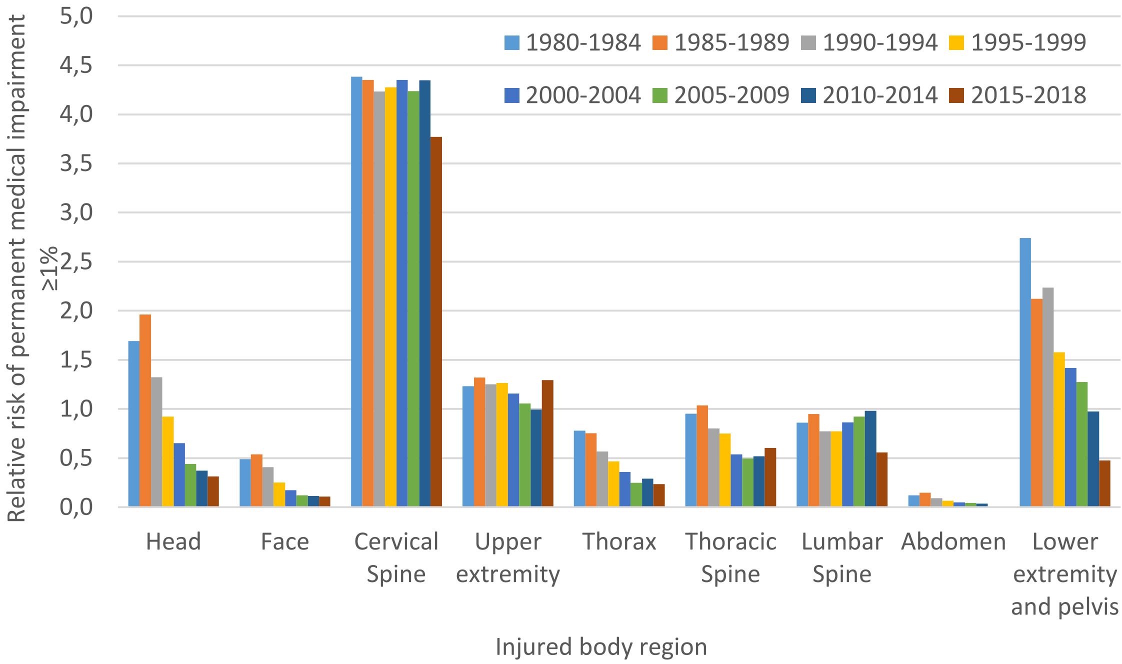

Figure 2. Relative risk, within body region, of injury resulting in permanent medical impairment (PMI) ≥1%, between 1980 and 2018 (Source: Kullgren 2019[35]).

1.2 MEASURING HEALTH LOSS

The aim of Vision Zero is not to prevent all road traffic accidents, but those resulting in unacceptable health loss. To create a sustainable road transport system, in which the targets regarding not only fatalities but also injuries can be met, definitions what an unacceptable health loss is could be discussed. Health loss in the road transport system is today defined and measured in different ways. Depending on the methods and the definition of serious injuries, problem scenarios will differ substantially.

1.2.1 Assessment of injuries based on available data

Depending on which source that is used when studying road traffic injuries, the results will vary based on how the information is collected. Traditionally, road safety is measured using police-reported deaths and severe injuries,[36]. In many countries, the police reports the injury severity on three levels: fatality, serious injury, and slight injury[37, 38]. Several studies have shown that police records do not reflect the true injury outcome and that hospital data are more relevant to use[39, 40]. Data from emergency hospital care is also common when studying road traffic injuries. The Swedish Transport Agency holds the Swedish Traffic Accident Data Aquisition System (STRADA) database, with information about crashes reported by the police and injuries reported by emergency care hospitals[41]. Under-reporting is known to exist, both from the police and from the emergency care hospitals[41]. Another source of information is health care episodes registered by healthcare providers, such as the National Patient Register (NPR) held by the National Board of Health and Welfare, which contains information from the inpatient and specialized outpatient health care in Sweden[42]. In a comparison between the STRADA and NPR, STRADA was found to capture 63% and NPR 65% of all individuals reported injured in road traffic accidents in either of the two databases, and the correspondence between the two databases was low, only 30%[41]. Another source of information on road traffic injuries is insurance data based on the policyholders´ claims (see e.g., Stigson et al 2015[43]). Such reports are mandatory in order to receive payment for expenses and occupant injuries. This has the advantage of including also minor injuries that are not reported by the police or healthcare. In Sweden, motor vehicle insurance is mandatory[44], which means that injuries sustained in accidents with all cars will be covered.

1.2.2 Definitions of serious injury

Another factor of importance for the results when studying road traffic injuries is how injury severity is measured. In order to achieve international and national road safety goals, targets have been set up by policy makers. From a successful focus on reducing the number of fatalities among car occupants involved in crashes in recent decades, policies in many western countries now focus increasingly on also preventing serious injury. How serious injury is defined and used in the selection of targets will result in different pictures of the problem of injuries from these crashes. In this way, it is linked to the prioritizations and consequently to which preventive measures are taken in road traffic safety strategies. The Abbreviated Injury Scale (AIS) is commonly used to describe the nature of road traffic injury by type, location, and severity[45]. The severity score is mainly based on the direct threat to life that the injury constitutes, and is categorized on a 6-point scale, where a minor injury is classified as 1 and maximal severity as 6. Maximum AIS (MAIS) is the highest AIS score of an individual. The European Union uses a MAIS 3+ (including all injuries with a AIS score of 3 or higher) definition of serious injury[15]. Road traffic injuries on the MAIS 3+ level have been shown to only include 14% of injuries resulting in permanent medical impairment (PMI), and MAIS 2+ to include 63%, while 37% of all injuries resulting in PMI where classified as AIS 1 injuries[40]. These differences in the picture of the problem of road traffic injuries depending on the definition of serious injury will result in different prevention strategies. It is clear that a too high threshold will result in that injuries with long-term consequences for the injured are not prioritized. The International Traffic Safety Data and Analysis Group (IRTAD) has suggested MAIS 3+ as a cut-off for serious injuries, but recognizes the need to study other types of consequences as well, e.g., lifelong disability[46]. Another suggestion of cut-off is MAIS 2+ with the addition of injuries on the AIS 1 level that often lead to long-term consequences[40].

As mentioned in section 1.1.1, the Vision Zero defines serious injury as one resulting in unacceptable health loss, in Sweden defined as RPMI ≥1%. Furthermore, the Swedish Transport Administration also uses RPMI ≥10% as a definition of very serious injury[47]. The RPMI estimates the risk of permanent medical impairment (RPMI) based on loss of physical and/or mental function[48]. Permanent medical impairment is a set of grading rules used by Swedish insurance companies to assess medical impairment caused by injury[49]. It defines injury and assess long-term impairment strictly from a biomedical perspective. Grading is conducted by consultant physicians, in cases where injured claimants have not recovered within two years. All medical records from before and after the crash are used in the assessment, where a degree of impairment based on the reduction in function caused by the injury is determined. If an injured occupant receives multiple diagnoses that result in medical impairment, a cumulative value of impairment is set. The impairment grade can be between 1 and 99%. Road traffic injury causing permanent impairments are compensated in accordance to PMI grade through the mandatory motor vehicle insurance[44]. This is a third-party liability insurance compensating injuries of anyone involved in a crash with the motor vehicle, both occupants of the insured vehicle and individuals outside of the vehicle. Cases with injuries resulting in PMI ≥10%, or where the injured occupant so requests, is assessed by the Road Traffic Injuries Commission to assure that compensation is reasonable and uniform[50].

With the definitions of serious injury and very serious injury based on RPMI, the numbers of seriously and very seriously injured in road traffic in Sweden are estimations based on the registered injury diagnosis and the corresponding RPMI[51]. It has been found that almost 10% of car occupants with a minor injury, according to the AIS scale, have an injury resulting in PMI[48]. As can be seen in Table 1, regarding some body regions, injuries with low AIS scores have a relatively high RPMI at the ≥1% level. Out of AIS 1 injures to the upper extremities, lower extremities, or cervical spine, around 17% result in a RPMI of ≥1%. Injuries to the cervical spine is also the injury type with the highest number of injuries resulting in PMI[43]. Injuries to the upper and lower extremities, however, have the highest RPMI, as seen in Table 1. Women generally have higher RPMI when injured than men, e.g., regarding whiplash injuries[52]. Further, older age is associated with higher RPMI[52] and rollover is the crash impact direction associated with the highest RPMI[43]. The proportion of injured occupants with PMI have been found to be lower in more modern cars compared to older cars[53, 54].There is, however, a lack of knowledge regarding to what extent PMI reflects the future situation of individuals injured in a crash, measured in other terms of health loss.

Table 1. Risk of permanent medical impairment (RPMI) on the ≥1% and ≥10% level respectively, stratified by Abbreviated Injury Scale (AIS) level and body region. Numbers in percent. Source: Malm et al.[48].

	RPMI ≥1%					RPMI ≥10%				
Body region	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	8.0	15	50	80	100	2.5	8	35	75	100
Cervical Spine	16.7	61	80	100	100	2.5	10	30	100	100
Face	5.8	28	80	100	100	0.4	6	60	60	n.a.
Upper Extremity	17.4	35	85	100	n.a.	0.3	3	15	100	n.a.
Lower Extremity & Pelvis	17.6	50	60	60	100	0.0	3	10	40	100
Thorax	2.6	4.0	4	30	30	0.0	0	0	15	15
Thoracic Spine	4.9	45	90	100	100	0.0	7	20	100	100
Abdomen	0.0	2.4	10	20	20	0.0	0.0	5	5	5
Lumbar Spine	5.7	55	70	100	100	0.1	0.1	6	100	100
External (Skin) % Thermal Injuries	1.7	20	50	50	100	0.03	0.03	50	50	100

n.a.: not applicable (injuries in these body regions do not result in this severity grade)

1.2.3 Factors influencing injury risk and its long-term consequences

Vehicle safety is one important part of a safe road transport system. Improving vehicle safety is considered one of five key pillars to achieving the goal of the decade of action for road safety[55]. It has been shown that vehicle crashworthiness has improved steadily since the 1980s, with lower risks of both fatal and serious injuries, as well as injuries resulting in PMI among occupants in newer cars compared to occupants in older[54]. The injury outcome from real-world crashes has also been found to be correlated with car safety performance assessments based on crash tests, such as the European New Car Assessment Programme (Euro NCAP) rating. Occupants in five-star rated cars have a lower risk of sustaining an injury compared to occupants in two-star rated cars, while controlling for car mass and model year[54]. The structural performance of cars has been upgraded which has resulted in less intrusion into the passenger compartment and occupant protection systems like airbags have been introduced to limit the forces that occupants are exposed to during the crash phase. Still seat belt is the most effective safety system by keeping the occupant in a stable position and reducing the risk of serious and fatal injuries by approximately 40%[56, 57]. Seat-belt reminders in modern cars have been shown to increase seat-belt use[58], and seat-belt use has been shown to dramatically reduce the risk of getting injured[59]. Furthermore, the development of active safety technology, with advanced safety technologies aimed at reducing the crash or injury risk, has showed good results. Electronic Stability Control that was introduced 1998 has been shown to effectively reduce the injury risk, especially serious and fatal injuries[60-62]. Another modern car safety system aiming at avoiding or mitigating crashes is Autonomous Emergency Braking, which has been shown to dramatically reduce road traffic casualties[63, 64]. Furthermore, older car occupants involved in a crash have been found to have a higher risk of injury compared to younger[65, 66], and women have been found to have a higher injury risk compared to men[67, 68].

Whiplash injuries/whiplash associated disorders (WAD)

Whiplash injuries are one of the most common injury types resulting from car crashes, constituting nearly half of all injuries[48, 52]. The injury mechanism behind whiplash injuries has been debated. Whiplash-associated disorders (WAD) is a term describing the clinical symptoms related to whiplash injuries[69]. According to the AIS classification WAD has a low severity grade (AIS 1) and compared to other AIS 1 injuries, WADs have a high RPMI, only injuries to the extremities have a higher RPMI ≥1% (Table 1,[48]). However, due to higher incidence, WAD is the injury type with the largest number resulting in PMI[43, 52]. Women have been found to have both a higher injury risk and RPMI compared to men regarding WAD[52, 70]. Due to the frequency and potential long-term consequences, WAD is a major concern to society.

Out of WADs resulting in PMI, 44% occurred in rear impacts, 39% in frontal, and 18% in side impacts[53]. The potential to address WADs differ depending on the impact direction. In frontal impacts, airbags in combination with seatbelt pre-tensioners reduce the number of WADs[71]. In rear impacts, the seat design has been shown to influence the risk of injury and

PMI[53]. Several concepts aimed at reducing the risk of WAD have been introduced on the market[72-74]. To lower the risk of WAD in rear-end crashes some main methods can be identified; minimizing of the relative motion between head and torso, controlling the energy transfer between the seat and the human body and/or absorbing energy in the seatback. Reactive head restraint (RHR) was first introduced by Saab in 1998[72]. Reactive head restraints have been used by several car manufacturers, e.g., Audi, Ford, Mercedes Benz, Nissan, Opel, Seat, Skoda and Volkswagen. In RHR, the head restraint reacts to the pressure from the occupant's torso to the seat back that occurs in rear-end crashes, and moves forward and up to support the head[72]. Besides the moving reactive head rest, it also includes an improved seat back design. The WHIPS system is a reactive seat developed by Volvo[73]. With the increased pressure from the occupant's torso to the seat back in rear-impacts, the system reacts by moving rearwards and into a reclined position, in order to keep the acceleration of the occupant low while giving support to the back and head of the occupant[73]. The WHIPS system has also been used by Jaguar. Passive seats (PAS) are seats without active or reactive parts. Instead the design of the seat is improved, in terms of energy absorbing material of the seat back and geometry. PAS was first introduced in cars by Toyota in 1999[74]. The aim is to absorb energy into the seat during the crash phase and thus having the upper torso of the occupant move into a position where the head engages the head restraint with less motion of the neck. Most car manufacturers have lately been introducing this concept, e.g., Audi, VW, and Ford. Another, later introduced, concept is the proactive head restraints (PAHR), in which sensors in the vehicle activates the head restraint very early in the crash phase or even before the crash occurs, moving it forward and upward in order to reduce the distance between head and head restraint. PAHR have e.g., been used by Mercedes Benz and BMW.

1.2.4 Sickness absence and disability pension

Road traffic injuries may result in different types of social and economic consequences for the individual. One such important consequence is that it might lead to work incapacity and thus loss of income from work[75, 76].

Disease and injury may cause a reduction of an individual's work capacity. Many countries have social security systems that can provide compensation for loss of income in the case of such work incapacity, where an individual may qualify for temporary benefits in case of short-term work incapacity (here called sickness absence (SA)) or more long-lasting benefits in case of permanent or long-term work incapacity (here called disability pension (DP))[75, 77-79].

The social insurance systems differ somewhat between countries, also with regards to rules of compensation of income loss due to work incapacity, e.g., requirements and qualifications for compensation, compensation levels, and duration of compensation[75, 79]. Also, different terms have been used in different countries and during different periods for similar concepts. For example, short-term work incapacity due to disease or injury is addressed by different terms, such as sickness absence, sick leave, work disability, or compensated time off work. Permanent or long-term work incapacity can be named disability pension, disability benefits, incapacity benefits, early pension on medical grounds, incapacity pension, incapacity retirement, medical retirement, ill health retirement or work disability pension. To facilitate international comparisons, the Organisation for Economic Co-operation and Development (OECD) have included all spells of sickness absence benefits longer than two years under the definition of disability pension benefits, here called DP[79].

As stated above, in this thesis, the terms SA and DP are used. Based on a holistic perspective on health, and understanding health as a resource of importance for the ability to achieve essential goals, work incapacity may be an appropriate measure of consequences of health loss[80, 81]. Work incapacity and compensation for income loss that this can lead to are very complex issues. The prevalence and incidence of SA and DP are influenced by many factors, not least changes in social insurance regulations[75]. Both SA and DP have been found to be associated with sociodemographic factors such as age, sex, level of education, marital status, and country of birth as well as with previous SA/DP[82, 83]. Few previous studies have examined SA after road traffic injuries, and even fewer have examined such DP. Sickness absence and DP are also operationalized in very different ways in the published studies, which makes comparisons difficult. The few published studies are often restricted to specific diagnoses or include only severe injuries. Furthermore, studies do often not exclude individuals who are not at risk of SA or DP (e.g., those not eligible due to age, not being insured, or already being on SA or DP). Further, some studies use self-reported information on SA/DP rather than register data, with a risk of bias, e.g., recall bias and drop outs[84-86]. So far, there are only two previous studies on the association between PMI and SA and DP among injured car occupants[87, 88]. There is a lack of studies investigating work capacity after road traffic crashes, in terms of SA and DP, in large study populations that include all types of injuries, while taking into account also SA and DP prior to the crash.

Sickness absence and disability pension benefits in Sweden

The Swedish public SA insurance system covers all residents in the country aged 16 and above, who have income from work, unemployment benefits, or parental-leave benefits. The first seven days of a SA spell can be self-certified by the individual. After that, a medical certificate from a physician is required. Sickness absence benefits can be granted to those covered by the SA insurance system, who, due to disease or injury, have a reduced work capacity. The work capacity is to be determined in relation to work demands of the claimant’s job or other jobs at the labour market. The first day of a SA spell is an unreimbursed qualifying day. For employed individuals, day 2-14 are reimbursed by the employer as sick pay. When a SA spell exceeds 14 days, an individual can receive SA benefits through the Social Insurance Agency who assess, determine and administer such benefit claims[78]. Unemployed individuals are reimbursed by the Social Insurance Agency after the first qualifying day, while self-employed can have a qualifying period of between 1 and 90 days. Sickness absence benefits cover 80% of lost income, up to a certain level[78].

Disability pension can be granted to individuals living in Sweden and aged 19-64 years who, due to disease or injury have a long-standing or permanent reduction of their work capacity. Young adults, aged 19-29 can be granted temporary DP for such work incapacity or if they are not able to complete compulsory or upper secondary school studies in the intended time[89]. From 1 July 2008, only permanent DP can be granted to individuals from the age of 30 years.[89]. DP is compensated in part to a guaranteed amount depending on age and other factors, and in part through income-related additional coverage with about 65% of lost income up to a certain level. Sickness absence and DP can be reimbursed for full- or part-time, i.e., 100, 75, 50, or 25% of ordinary work hours[89].

Measures of SA and DP

Sickness absence and DP can be studied in a variety of ways. In order to facilitate interpretation and comparison of studies, they can be categorized according to the structure presented in Table 2, where the perspectives relevant to this thesis are marked in bold.

Table 2. A structure for categorisation of studies of sickness absence and disability pension. Perspectives relevant in this thesis are marked in bold[90].

What is studied?	-Study design -Type of data -Analyses	Scientific discipline	Perspective taken in the research questions	Studied	Structural level of the factors included in the analyses	Diagnoses[1]
1. **Occurrence of sickness absence/disability pension** 2. Factors that hinder or promote sickness absence/disability pension 3. Factors that hinder or promote return to work 4. "Consequences" of (being on) sickness absence/disability pension 5. Sickness certification practice 6. Methods, theories	**Study design** **-Cross sectional** **-Longitudinal** -RCT, CT, etc. **Type of data** Interview Questionnaire **Register** Medical files Insurance files Certificates Documents Observations Video Other **Type of analyses** -Qualitative **-Quantitative**	Economy (health economy) **Epidemiology** Law Management **Medicine (insurance medicine,** psychiatry, occupational health, social medicine, healthcare science, **public health**, etc) Philosophy Psychology Social work Sociology Other	That of the: -**Society** -**Insurance** -Healthcare -Employer -Colleagues -Family -Patient	**-General population** **-Insured** -In paid work (general or special jobs/organizations) -**Diagnosed/patients** -Sickness absent /disability pensioned -Organizations -Professionals -Countries	-National -Local -Worksite -Health care -Family -**Individual**	**All together** **Mental** (all or specific) **Musculoskeletal** Cancer MS Hearing CVD Infections **Injuries** Diabetes Etcetera

[1] Of included individuals and/or of sickness absence or disability pension diagnoses

To get a better understanding of road traffic injuries and their consequences, knowledge has to be generated about different aspects of the future situation of those injured. Knowledge is also needed on how different methods to measure this could be used to provide information from different perspectives. Consequences of road traffic injuries can, of course, be studied on different structural levels. In this thesis, the future situation of the injured car occupant is considered, regarding sickness absence (SA), disability pension (DP), permanent medical impairment (PMI), and long-term (symptoms >4 weeks) WAD among injured individuals.

2 AIM

The *overall aim* of this thesis was to generate deeper knowledge on SA, DP, and PMI, and on how they are related, among individuals in working ages, injured in car crashes.

The *specific aims* of the four studies were to:

Study I: investigate the occurrence of already ongoing SA and DP, and of new SA spells >14 days, in general and for different initial injury diagnosis, among car occupants receiving medical healthcare after being injured in a crash.

Study II: investigate SA, DP, and PMI, among injured car occupants two years after the crash date, and how they are associated, accounting for sociodemographics, previous SA/DP, and crash-related factors.

Study III: investigate SA and DP by diagnoses among injured car occupants, before and after a crash, and future PMI. A secondary aim was to explore the associations between factors related to the injury and to the safety level of the car with number of SA/DP days during year two and year four, respectively, after the crash, while taking sociodemographics into account.

Study IV: investigate long-term WAD, PMI, and SA/DP (all SA/DP and SA/DP with WAD diagnoses, respectively) among front seat car occupants with WAD injuries sustained in rear-end crashes, accounting for sociodemographics. A secondary aim was to investigate the associations of car seat design with future long-term WAD, and future PMI, and SA/DP.

3 MATERIAL AND METHODS

The four explorative studies included in this thesis were based on data from four Swedish nationwide registers, and in Study II-IV also data from Folksam Insurance Group (Folksam). Study I was population based, study II-IV were based on the data of injured occupants, involving a car insured at Folksam. Figure 3 illustrates how the study populations are related to the available data sources of road traffic injuries. More detailed descriptions of the methods are found in each respective study.

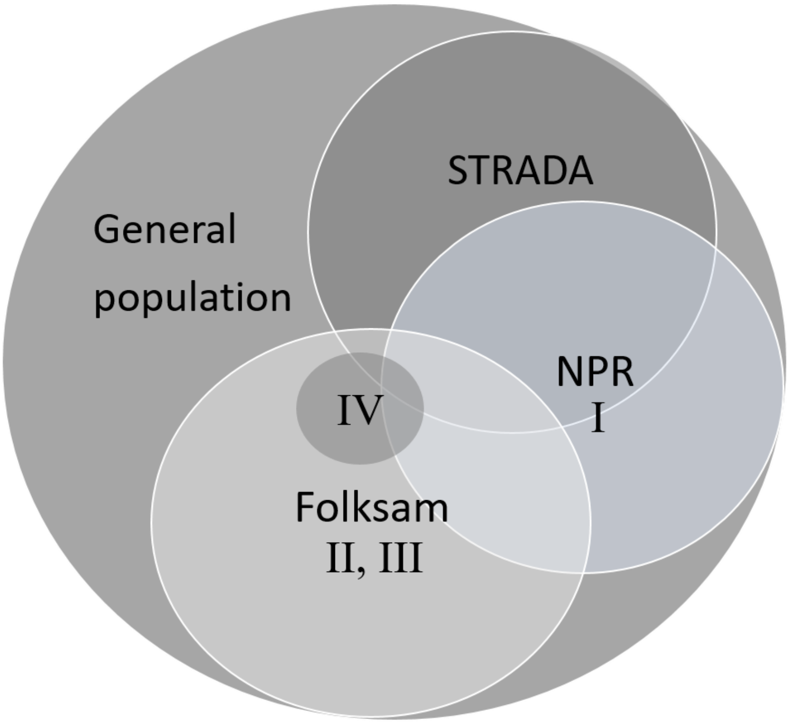

Figure 3. An illustration of the relationship between data sources available, with the studies in this thesis marked I-IV. Circle size and overlap are not to actual scale.

3.1 STUDY I: DESIGN AND STUDY POPULATION

Study I was a cross-sectional study including all individuals aged 16-64 years, living in Sweden on 31 December 2009, who in 2010 had in- or specialized outpatient healthcare due to injuries from road traffic crashes in which they were car occupants (N=13,948). The age range 16-64 was chosen in order to have a population at-risk of SA and DP, that is, regarding age could claim and be granted such benefits. The injured individuals were identified through the external causes of morbidity codes V40-V49 (Car occupant injured in transport accident) of the Swedish version of ICD-10, which is registered by national healthcare services in relation to healthcare visits[91]. Individuals who at any time during the three years prior to the date of the inclusion healthcare visit had been treated for a transportation-related crash injury were excluded (n=1520). This to ensure that the healthcare visits were due to new car crashes. Excluded were also those injured in non-road traffic situations (n=1887), and those who had died from their injuries, defined as dead ≤30 days after the healthcare visit (n=99). Exclusions were also made of those who neither had an injury diagnosis code (S00-T98) nor the code Z04.1, “Examination and observation following transport accident” (n=895). Further, those with codes T90-T98 stating late effects (>1 year) of injury, indicating that the injury was not sustained close in time to the healthcare visit (n=120), were also excluded. The final cohort thus comprised 9427 individuals. Prevalent SA and DP at the time of the healthcare visit, as well as incident SA were investigated. Associations of sociodemographic factors, and injury type with incident SA were assessed.

3.2 STUDY II – IV: DESIGN AND STUDY POPULATIONS

Study II was a prospective cohort study including individuals injured as car occupants reported to Folksam. All occupants injured in crashes between 2001 and 2013, aged 17-62 years at the year of the crash were included. This age range was chosen in order to have a population at-risk of DP, regarding age-related eligibility, at the end of follow-up. Excluded were those who died from their injuries, defined as dead ≤30 days after the crash, or who had another crash during the two-year follow-up. This resulted in a cohort of 64,007 individuals. Prevalent SA and DP at the time of the crash, and SA and DP status at follow-up two years later, as well as PMI grade resulting from the injuries were investigated. Associations of sociodemographic factors, SA status at inclusion, impact direction, car model year (MY), and PMI grade with DP at follow-up were assessed. Furthermore, associations of sociodemographic factors, SA and DP status at inclusion, impact direction, MY with subsequent PMI determined for the injuries were also investigated.

Study III and IV were longitudinal cohort studies using subsets of the cohort in Study II. Included in Study III were the 63,358 individuals from Study II, whom did not have a new crash reported to Folksam within four years following the crash. Mean number of SA/DP net days per year in relation to the crash, for a period of two years before and four years after the crash, was calculated by diagnosis category, taking loss to follow-up in terms of death or migration into account. Associations between injured body region, factors related to the safety level of the car, such as model year of introduction (MYI) and Euro NCAP star rating, and number of SA/DP net days during year two and four after the crash was assessed.

Included in Study IV were front seat car occupants who reported WAD from a rear-end crash. Excluded were those with a new crash registered with Folksam within three years following the crash. This resulted in a cohort of 14,363 individuals. Mean number of SA/DP net days per year in relation to the crash, for a period of two years before and three years after the crash, was calculated, taking loss to follow-up in terms of death or migration into account. Associations between car seat design and long-term WAD (symptoms ≥four weeks), PMI, and number of SA/DP net days in year two were assessed. Table 3 provides an overview of the four studies in this thesis.

Table 3. Overview of the four studies of the thesis

	Study I	**Study II**	**Study III**	**Study IV**
Aim	To investigate the occurrence of already ongoing SA and DP, and of new SA spells >14 days, in general and for different initial injury diagnosis, among car occupants receiving medical healthcare after being injured in a crash.	To investigate SA, DP, and PMI, among injured car occupants two years after the crash date, and how they are associated, accounting for sociodemographics, previous SA/DP, and crash-related factors	To investigate SA and DP by diagnosis among injured car occupants, before and after a crash, and future PMI. And to explore the associations between factors related to the injury and to the safety level of the car with number of SA/DP days during year two and year four, respectively, after the crash, accounting for socio-demographics	To investigate long-term WAD, PMI, and SA/DP (all SA/DP and SA/DP with WAD diagnoses, resp.) among front seat car occupants with WAD injuries sustained in rear-end crashes, accounting for sociodemographics. A second aim was to investigate the associations of car seat design with future long-term WAD, and future PMI, and SA/DP.
Design	Population-based cross-sectional study	Prospective cohort study	Prospective cohort study	Prospective cohort study
Data sources	LISA[1], NPR[2], Cause of Death Register, MiDAS[3]	Folksam, LISA[1], Cause of Death Register, MiDAS[2]	Folksam, LISA[1], NPR[2], Cause of Death Register, MiDAS[3]	Folksam, LISA[1], NPR[2], Cause of Death Register, MiDAS[3]
Study population ; N	9427 (16-64 years, 48% women)	64,007 (17-62 years, 51% women)	63,358 from the Study II cohort (51% women)	14,363 from the Study II cohort (51% women)
Inclusion criteria	Living in Sweden 31 December 2009: Receiving in- or specialized outpatient healthcare in 2010 for injuries sustained as car occupants in a road traffic crash, no transportation related injury during three years prior to inclusion, not dead within 30 days of crash	Injured in car crash between 2001 and 2013, reported to Folksam. No new crash within the two-year follow-up period. Not dead within 30 days of crash. On 31 December the year before the crash: Living in Sweden, aged 17-62 years	Same as Study II + no new crash within the four-year follow-up period	Same as Study II + front-seat car occupants reporting WAD after a rear-end crash and no new crash within the three-year follow-up period was included
Outcome measures	SA >14 days	SA >14 days and DP two years after the crash. Resulting PMI from the injuries	Mean annual net days of SA/DP overall and by SA/DP diagnoses during the two years before and four years following the crash. 90-180 and >180 SA/DP days in year two and four after the crash	Mean annual net days of SA/DP during the two years before and three years following the crash. >90 days SA/DP in year two after the crash, long-term WAD, WAD resulting in PMI
Factors included in the analyses	Sex, age, educational level, country of birth, marital status, type of living area, crash type, medical care, injury type	Sex, age, educational level, country of birth, marital status, SA/DP status at the crash date, crash impact direction, model year, SA and DP two years after the crash, PMI	Sex, age, educational level, country of birth, marital status, SA/DP status at the crash date, model year of introduction, Euro NCAP star rating, injury, PMI	Sex, age, educational level, country of birth, marital status, previous SA, already ongoing SA/DP at the crash date, model year of introduction, car size, year of the crash
Statistical analyses	Calculation of ORs for associations between injury type, sociodemographics and new SA in relation to the crash. Stratified by age	Calculation of ORs for associations between sociodemographics, MY, crash-related factors and SA, DP, in year 2 after crash and PMI	Calculation of net days of SA/DP per year. Calculation of ORs for associations between injured body region MYI, Euro NCAP rating and 90-180, >180 days SA/DP in year 2 and year 4 after crash	Calculation of net days of SA/DP per year. Calculation of ORs for associations between car seat design and long-term WAD, PMI, >90 days SA/DP in year 2 after crash. Stratified by sex

[1]LISA: Longitudinal Integration Database for Health Insurance and Labour Market Studies, Statistics Sweden
[2]NPR: National in- and specialized outpatient register, National Board of Health and Welfare
[2]MiDAS: Micro Data for Analysis of the Social Insurance, Swedish Social Insurance Agency
SA: sickness absence, DP: disability pension, PMI: permanent medical impairment, OR: odds ratio, MY: car model year, MYI: car model year of introduction

3.3 DATA SOURCES

In all four studies de-identified microdata obtained from four Swedish nationwide registers administered by Swedish authorities was used. Study II, III, and IV also used insurance data from Folksam. Data from the different sources were linked at an individual level, by the use of the ten-digit personal identity numbers which are assigned to all individuals living in Sweden[92]. The five data sources and the data are further described below.

3.3.1 Longitudinal Integration Database for Health Insurance and Labour Market Studies (LISA)

The Longitudinal Integration Database for Health Insurance and Labour Market Studies (LISA) is administered by Statistics Sweden. It contains sociodemographic and economic information, recorded annually on 31 December, on all individuals aged 16 or older and living in Sweden[93]. In the four studies, information from LISA regarding sex, age, educational level, birth country, type of living area, marital status, and if living in Sweden, was used.

3.3.2 The National Patient Register (NPR)

The National Patient Register (NPR) is administered by the National Board of Health and Welfare, and contains information about in- and specialized outpatient healthcare. It does not include information from outpatient primary healthcare, i.e., care by general practitioners. Healthcare providers are required to register all healthcare encounters. Diagnoses are coded according to the Swedish version of the International Classification of Diseases (ICD). The quality of the register is considered high. For 99% of registered healthcare encounters, there is a diagnosis code, and 98% of specialized healthcare with injuries have a stated injury cause[42].

In Study I, this register was used to identify all injured car occupants having visits to in- or specialized outpatient healthcare facilities during 2010, and to exclude individuals with transportation related injuries three years prior to the inclusion healthcare visit. In Study III and IV, the register was used to obtain information on injury diagnoses from healthcare visits. Identification was possible through the external causes of morbidity codes of the ICD-10.

3.3.3 Folksam Injury Database

Folksam is one of the largest Swedish insurance companies, with a market share of approximately 20%, considered representative of the general population. The Folksam data has information regarding individuals injured in crashes with cars insured by Folksam. For example, position in the car, injury, and if the injury resulted in PMI, and compensations paid for the injury. Information regarding the car and the crash, such as Euro NCAP star rating, MY/MYI, and impact direction was also obtained from Folksam.

In Study II, III, and IV, the Folksam data was used to identify car occupants injured in crashes during 2001-2013. Information from Folksam was also used to exclude individuals with a new crash during the follow-up periods of Study II-IV, respectively.

3.3.4 Micro Data for Analysis of the Social insurance (MiDAS)

Micro Data for Analysis of the Social insurance (MiDAS) is administered by the Swedish Social Insurance Agency. It contains information on SA and DP with benefits from the Social Insurance Agency, regarding start and end date of spells, extent (full- or part-time) of spells, and diagnoses coded according to the ICD-10[94] at three-digit level. This information was used to examine SA/DP status at the crash date and at follow-up, as well as to calculate net days of SA/DP per year in relation to the crash.

3.3.5 The Cause of Death Register

The Cause of Death Register is administered by the National Board of Health and Welfare, and contains information on dates and causes of deaths among all individuals registered as residents in Sweden[95]. This information was used to exclude individuals who died within 30 days of the crash and to identify individuals who died during the follow-up of the studies.

3.4 EXPOSURE, COVARIATES, AND OUTCOME MEASURES

In the studies, information describing the included individuals in terms of sociodemographics and already ongoing SA/DP was used. Information on crash-related factors was also included in all studies. Study I, III, and IV used information on injury type. The included sociodemographic, injury-, and crash-related factors were selected based on their possible associations with SA, DP, and PMI reported in previous studies.

3.4.1 Injury-related factors

Information on several injury-related factors were used in different ways.

3.4.1.1 Injury diagnosis and the Barell matrix

In Study I, injury diagnoses coded according to ICD-10 were obtained from the NPR. A majority (79%) of the individuals had only one unique diagnosis code. For the remaining 21%, a selection was made to reach one code per individual. The following selection hierarchy was used: main diagnosis > secondary diagnoses, inpatient care diagnosis > outpatient care diagnosis, and injury diagnosis > other types of diagnoses. In Study I, medical care in relation to the crash, in terms of specialized outpatient or inpatient healthcare, and duration of inpatient healthcare stay, was used in descriptive statistics. It was not included in the logistic regression analyses, as it was considered to be on the causal pathway between injury and SA.

In Study I and III, modified forms of the Barell matrix[96] were used in order to create meaningful categorization of the injuries. The Barell matrix classifies ICD-9-CM codes into 12 columns representing nature of injury and 36 rows representing body regions, assigning each code to a specific cell of the matrix. The matrix was modified by combining cells into wider categories, suitable for the data used in each study. In Study I, the ICD-10 codes from the National Patient Register were mapped into the matrix, and the ICD-10 code Z04.1, examination and observation following transport accident, was added. For the main analyses in Study I, a categorization of 10 injury types was created (Sprain of cervical spine (majority WAD), Concussion, Other traumatic brain injury, Other head, face and neck, Injuries to the vertebral column and spinal cord, Injuries to the torso, Injuries to an upper extremity, Injuries to a lower extremity, Other and unspecified, and Observation and complications). In an additional analysis, the Barell matrix categories for fractures to the torso, vertebral column, upper extremities, and lower extremities were used. In Study III, diagnoses from both the National Patient Register (ICD-10) and from Folksam (AIS) were used. This was done to gain detailed injury information for as many of the injured occupants as possible. The diagnoses were coded according to location and nature of injury, based on a modified version of the Barell matrix. This was done in order to create a uniform categorisation, able to compare between ICD and AIS coded diagnoses and between injury diagnoses and the SA and DP diagnoses from MiDAS. For further analysis, a categorisation of six injury regions was created (head, torso/back (which included injuries to the neck, thorax, abdomen, lower back, lumbar vertebral column and spinal cord, and pelvis), upper extremities, lower extremities, other (which included unspecified injury and unspecified injury location), and multiple injuries (>1 injury diagnosis)).

In Study IV, information regarding injuries reported to Folksam was used, and in the case of no such information in the Folksam database, the ICD-10 code S134 (Sprain and strain of cervical spine) from the NPR were used to identify individuals with WAD. Long-term WAD was used as an outcome and defined as having compensation from Folksam for four or more weeks, corresponding to a payment of at least 2000 SEK in the claims handling process.

3.4.2 Crash-related factors

In Study I, a variable for crash type, with information on single-car crash or type of collision partner, was constructed based on the ICD-10 external causes of morbidity codes obtained from the National Patient Register. In Study II, crash impact direction as well as information on MY was obtained from Folksam. Model year was categorised into five-year categories (≥1990, 1991–1995, 1996–2000, 2001–2005, 2006–2010). Crash impact direction and MY was used to control for in the regression analyses, and to assess associations with DP two years after crash, and determined PMI from the injuries sustained in the crash.

In Study III, model year of introduction (MYI) was used instead of MY to better reflect the car design. While MY give the specific calendar year in which the car was manufactured, MYI provides information about the year a car model with a certain safety level was introduced on the market. Significant improvements of safety level are thus reflected by MYI to a higher extent than by MY. Model year of introduction was categorised into five-year categories (≤1993, 1994-1998, 1999-2003, 2004-2008, 2009-2013). Information on the Euro NCAP star rating was obtained from Folksam and a variable was constructed with categories: 4-5 stars, 2-3 stars, and not tested. The MYI and the Euro NCAP variables were used as exposure in logistic regression analyses to assess associations with number of SA/DP net days during year two and year four after the crash.

In Study IV, the categorization of MYI from Study III was used. Furthermore, two variables were created based on the MYI and seat design information from Folksam. The first variable used three categories. Cars equipped with any whiplash protection system was grouped together in one category, and cars without whiplash protection systems were categorised according to MYI to reflect overall safety level of the car: No system with MYI ≥1998 and MYI <1998 when no system was available. The second variable categorised cars with whiplash protection systems according to type of concept, Proactive head restraints (PAHR), passive seats (PAS), Toyota´s version of a passive seat (PAS_TO), reactive head restraints (RHR), SAAB´s version of RHR (RHR_SHR) and Volvo´s reactive seat (WHIPS). Additionally, in this variable, cars without specific whiplash protection system were categorised as Standard seats (STD) if MYI ≥1998, and (MYI <1998). Information on car size was obtained from Folksam, and categorized into seven categories (Supermini, Small Family Car, Large Family Car, Executive Car, MPV, SUV, Missing). The year of the crash was categorized into three categories (2001-2004, 2005-2008, 2009-2013).

3.4.3 Sociodemographic factors

In all of the four studies, LISA was used to obtain sociodemographic information. The sociodemographic variables included in the studies were sex, age, educational level, country of birth, and marital status. In Study I, type of living area was also included. In the four studies, outcome variables were stratified on sociodemographic variables in descriptive analysis. In logistic regression analyses, sociodemographic variables were controlled for. In Study I and II it was also used to examine differences for different sub-groups when assessing associations with the outcome variables.

3.4.4 Measures of sickness absence (SA) and disability pension (DP)

Some different measures of SA and DP were used. In the four studies, information on SA regarding SA spells that had lasted for more than 14 days and were reimbursed by the Social Insurance Agency were included in the analyses. Figure 4 describes how SA and DP were measured in each of the four studies.

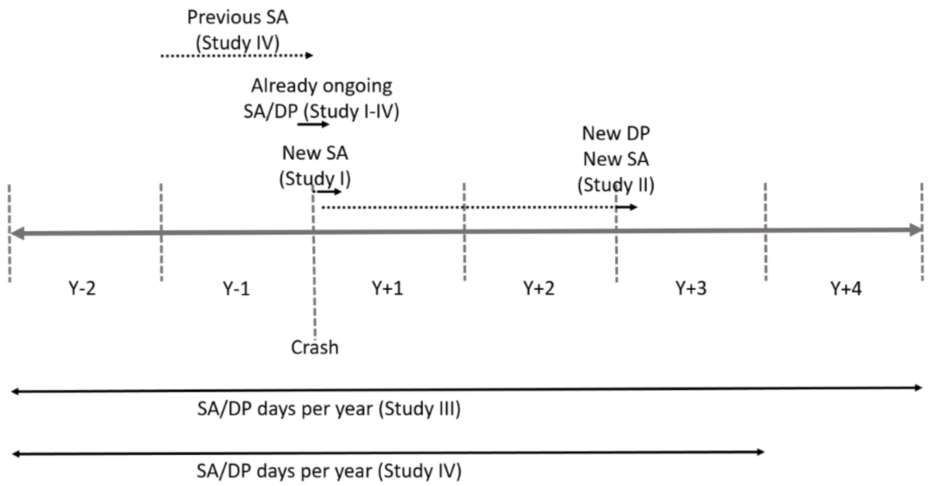

Figure 4. How sickness absence (SA) and disability pension (DP) were measured in the four studies in relation to time in years (Y_{-2} = two years before to Y_{+4}= four years after) before and after the date of the crash.

In Study I, individuals in the study population were identified through date of healthcare encounter (visit or admission) rather than date of crash. The crash, the healthcare encounter, and the start of a SA spell related to the crash, does not necessarily take place on the same day. Based on the distribution of start dates of SA spells in relation to the date of the healthcare encounter, a new SA spell was, therefore, defined as a spell starting ±4 days of the date of the healthcare encounter. Sickness absence spells that were ongoing already five days prior to, and DP that was ongoing at the date of, the healthcare encounter, were considered as already ongoing. That is, the patient was already on SA/DP when injured. Patients on part-time DP were still at risk for SA for the remaining percentage of working time. That is, if an individual was on DP for, e.g., 25% of full-time he or she could be on SA for 25, 50, or 75% of full-time at the same time.

In Study II, III, and IV, already ongoing SA and DP were defined as spells already ongoing at the date of the crash. The information regarding crash date was obtained from the Folksam database. In Study II, follow-up was defined as (365x2+6) days after the crash date. The six extra days were added to allow for the possibility of leap year, and for the possibility of SA spells not starting on the exact day of the crash. In this study, New SA was operationalised as having a SA spell lasting >14 days at the date of follow-up. New DP was defined as DP ongoing at follow-up, or SA spells starting within four days of the crash and ongoing at follow-up, i.e., spells with a duration of ≥ two years. This definition was used to facilitate international comparison[79].

In Study III, annual net days of SA and/or DP per diagnosis category (Injuries: ICD-10 codes S10-T98, Mental: F00-F99 + Z73, Musculoskeletal: M00-M99 and Other: all other codes and missing) was calculated for a period of two years before and four years after (Y_{-2}-Y_{+4}) the crash (T_0). Furthermore, two variables were created, for year two (Y_{+2}) and year four (Y_{+4}) after the crash respectively. One variable categorised the total number of SA/DP days as 90-180 (yes/no), and the other as >180 days/year (yes/no).

In Study IV, previous SA was defined as >90 net days SA/DP in the year before the crash. For the outcome, annual net days of SA and/or DP was calculated, for a period of two years before the crash and three years after (Y_{-2}-Y_{+3}) the crash (T_0). This was done for total SA/DP and for SA/DP with WAD diagnosis (ICD-10 code S13, “Dislocation, sprain and strain of joints and ligaments at neck level”). A variable was created where the SA/DP days during year two (Y_{+2}) after the crash was categorised into categories ≤90 and >90.

3.4.5 Measures of permanent medical impairment (PMI)

In study II and III, for occupants with injuries resulting in PMI, a total PMI grade for each individual based on his or her injuries was used. In Study II, PMI was, with the purpose of descriptive analysis, categorised: 0, 1-4, 5-9, 10-19, and ≥20, or: no PMI and PMI ≥1%, depending on analysis. As independent variable in the logistic regression, with DP at follow-up as outcome, PMI was categorised as: no PMI, PMI 1-4%, and PMI ≥5%. As outcome variable in logistic regression analysis, PMI was categorized as: no PMI and PMI ≥1%. In

Study III, PMI was categorised as: no PMI, PMI 1-4%, PMI ≥5% in the description of the cohort, and as no PMI or PMI ≥1% when used for stratification. In Study IV, WAD resulted in PMI was used to stratify on in descriptive analysis and used as an outcome in logistic regression analysis, and was categorised as: no PMI and PMI ≥1%.

3.5 STATISTICAL ANALYSIS

In Study I, descriptive statistics were used to describe the study population as well as crash and injury type, for all and stratified by sex. Descriptive statistics were also used to investigate the utilisation of medical care, prevalent SA and DP at the time of the crash as well as incident SA, for all, and stratified by age group and crash type. Crude and adjusted odds ratios (OR) and 95% confidence intervals (CI) for incident SA were calculated with logistic regression analyses. In the regression models, occupants with already ongoing SA or full-time DP, i.e., not at risk, were excluded. Univariable analysis was used to assess the association between factors potentially influencing the outcome; those found to have a statistically significant association were included in the adjusted models. The variable sex was included in the adjusted models. A multivariable model using injury type categories was created, mutually adjusting for all included covariates. For the purpose of investigating specific diagnosis groups, a second multivariable model was created. This model included only individuals with a selected diagnosis of fracture to the torso, the vertebral column or the upper or lower extremities. The regression analyses were stratified into age, with categories 16-44 years, and 45-64 years old.

In Study II, descriptive statistics were used to describe the study population, in total and stratified by sex. Proportions with already ongoing SA and DP at the time of the crash (inclusion date), as well as proportions with new SA at follow-up, and proportions with different grades of determined PMI were calculated. Descriptive analyses were also used to investigate SA and DP status at follow-up in relation to status at inclusion, for all and stratified by PMI. Logistic regression analyses were used to calculate crude and adjusted OR and 95% CI for DP and PMI status, respectively, at follow-up. For each of these outcomes, a mutually adjusted multivariable model was constructed. Included as independent variables were the factors identified through the literature that were available in the registers and found to have an association with the outcome in univariable analysis. In the regression analysis with DP at follow-up as an outcome, occupants with DP at inclusion, i.e., not at risk, were excluded. In the regression analysis with PMI as an outcome, the whole cohort was included. Factors included in the regression analysis were assessed regarding association with the outcomes in univariable analysis; if the association was significant, they were included in the multivariable analyses.

In Study III, descriptive statistics was used to describe the study population. Annual net days of SA/DP was calculated for a period of two years before through four years after the crash date (Y_{-2}-Y_{+4}). Mean number of SA/DP days was stratified on SA/DP diagnosis groups and calculated for those with PMI and those with no PMI. Individuals no longer at risk of SA and DP due to migration or death were not included in the calculations for relevant year(s).

Logistic regression analyses were used to calculate crude and adjusted OR and 95% CI for associations between injured body region, car safety, and SA/DP. Due to an expected strong correlation between MYI and Euro NCAP, separate models were created for these two exposures.

In Study IV, all analyses were stratified by sex due to the differences regarding risk of injury and PMI that is known to exist between women and men with regards to WAD [53, 97]. Descriptive statistics were used to describe the cohort. Annual net days of SA/DP was calculated for a period of two years before and three years after (Y_{-2}-Y_{+3}) the crash (T_0). Individuals having migrated or died were excluded for relevant years, due to not being at risk for SA/DP any longer. Proportions with outcomes long-term WAD, PMI, and >90 days of total SA/DP, and SA/DP with WAD diagnosis, respectively, during year two after the crash was calculated. Logistic regression analyses were used to calculate crude and adjusted OR and 95% CI for the association between seat design and the three outcomes. Multivariable models were constructed including factors based on previous literature. In the regression analysis with SA/DP as an outcome, those not at risk of SA/DP due to already ongoing DP at the time of the crash, migration, or death were excluded. In the regression analyses with long-term WAD and PMI as outcomes, the whole cohort was included.

For the statistical analyses, SAS 9.4 and IBM SPSS Statistics 24 were used. The project had ethical approval from the Regional Ethical Reviews Board of Stockholm.

4 RESULTS

This section summarizes the main findings from Studies I-IV. More information and detailed results can be found in each of the four studies.

4.1 STUDY I

Among the 9427 injured car occupants in study I (48% women), who received inpatient or specialized outpatient healthcare in 2010, Sprains of the cervical spine (including WAD), was the most frequent type of injury (27%). The second most frequent injury type was injuries to the head, face, and neck of other type than brain injuries, sprains of the cervical spine, and injuries to the vertebral column and spinal cord (24%).

In the cohort, 898 individuals (10%) had a new SA following the crash, while 834 (9%) already had an ongoing SA spell or were on full-time DP at the time of the crash. New SA spells had a median duration of 44 net days. A higher proportion of women than men had already ongoing SA or DP, while the proportions with new SA were similar. An age-related trend was found both for ongoing SA and DP, and new SA spells, with higher proportions with increasing age. However, no association was found between sex and new SA. The strongest associations with new SA was found for injury types (Table 4). Individuals with injuries to the spine or spinal cord were the most likely to have a new SA (the reference group being sprains of the cervical spine). Among the younger (16-44 years of age), injuries to the lower extremity was the injury type with the second highest OR. Among the older (45-64 years of age), this was traumatic brain injuries other than concussion.

Table 4. Mutually adjusted odds ratios (OR) with 95% confidence intervals (CI) for new sickness absence (SA) spell >14 days, for all, and stratified by age

	All (n=8593)	**Age 16-44 (n=6709)**	**Age 45-64 (n=1884)**
	Adjusted OR (95% CI)	**Adjusted OR (95% CI)**	**Adjusted OR (95% CI)**
Injury			
Sprain of the cervical spine (n=2281)	Ref	Ref	Ref
Concussion (n=339)	2.66 (1.80-3.93)	2.34 (1.46-3.74)	3.97 (1.91-8.25)
Other traumatic brain injury (n=83)	6.99 (4.04-12.08)	5.07 (2.45-10.48)	14.68 (5.80-37.17)
Other head, face and neck (n=2091)	1.18 (0.90-1.54)	0.93 (0.67-1.28)	2.14 (1.27-3.59)
Spine (Vertebral column and spinal cord) (n=392)	8.64 (6.45-11.57)	6.32 (4.42-9.05)	17.32 (9.85-30.48)
Torso (n=1277)	3.03 (2.36-3.89)	2.53 (1.88-3.41)	4.50 (2.75-7.37)
Upper extremity(n=906)	4.51 (3.49-5.82)	4.26 (3.17-5.74)	5.28 (3.15-8.84)
Lower extremity (n=527)	5.82 (4.39-7.73)	5.64 (4.08-7.81)	6.73 (3.75-12.05)
Other and unspecified (n=125)	2.06 (1.12-3.79)	1.98 (0.99-3.96)	2.49 (0.69-8.97)
Observation and complications (n=572)	0.93 (0.60-1.45)	0.81 (0.48-1.38)	1.38 (0.62-3.04)

4.2 STUDY II

In this cohort of car occupants reporting injury to Folksam (n=64,007), 8% of the injured occupants sustained a PMI. At the follow-up two years after the date of the crash (T_0), 2% among occupants who did not have an already ongoing SA or DP at the crash were on DP. Among individuals with PMI, the median PMI grade was 4% for both women and men (5% for those with DP at follow-up, 3% for those with no DP at follow-up). A distinct trend of increasing proportion on DP with higher PMI grades was found. When excluding those already on DP at the crash date, 10% of those with PMI 1-4% had a DP two years after the crash date, in the group with a PMI ≥20% this proportion had increased to 75% (Figure 5). Results from logistic regression further points to this trend as occupants with higher PMI grade were more likely to have a DP at the two-year follow-up, compared to those with no PMI (PMI 1-4% OR: 4.2; 95% CI: 3.6-5.0, PMI ≥5% OR: 27.4; 95% CI: 23.9-31.5).

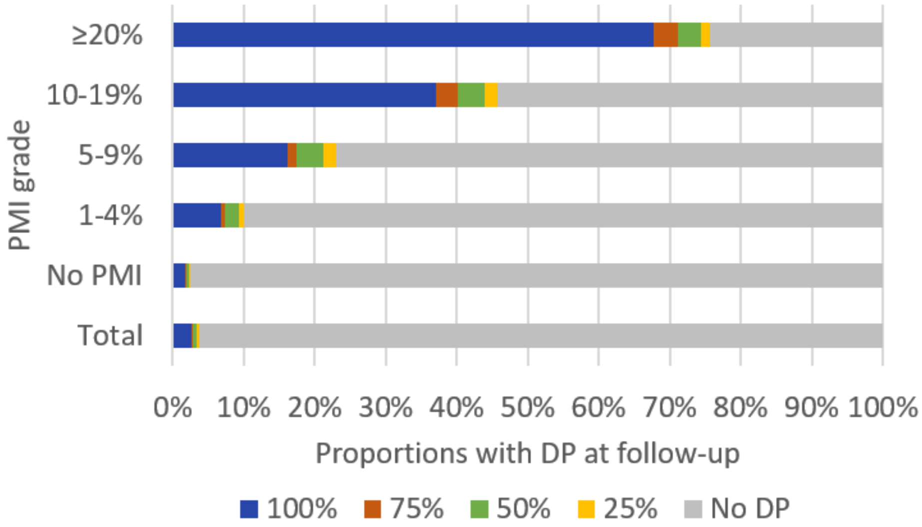

Figure 5. Proportion (%) of car occupants on disability pension (DP) two years after being injured in a crash, stratified by grade of permanent medical impairment (PMI), among occupants not already on DP at the date of the crash (n=58,252). DP grade (% of ordinary working hours) is shown by different colors.

In contrast to Study I, type of crash was found to be associated with PMI and DP at follow-up. Being injured in a rear-end crash was associated with a lower OR of both PMI (OR: 0.92; 95% CI: 0.85-0.98) and DP (OR: 0.86; 95% CI: 0.76-0.97) at follow-up, compared to frontal crash. Side impact was also associated with a lower OR of PMI (OR: 0.87; 95% CI: 0.79-0.94), while occupants injured in a rollover were more likely to have a PMI (OR: 1.4; 95% CI: 1.3-1.6), compared to occupants injured in frontal crashes. The safety level of the car, as represented by MY, was found associated with both PMI and DP two years after the crash. Compared to occupants of cars with MY 2006-2010, occupants of older cars were more likely to have PMI (MY ≤1990 OR 3.4; 95% CI: 2.7-4.2) and DP (MY ≤1990 OR 2.7; 95% CI: 1.8-4.1).

The strongest association with DP at follow-up was however found for already ongoing SA at the date of the crash (OR: 39.2; 95% CI: 34.9-44.0). An association was found between age and DP at follow-up, the ORs were higher in older age groups, compared to those 17-24 years of age. Individuals ≥25 years old were also more likely than those aged 17-24 to have injuries resulting in PMI. Women were found more likely to have injuries resulting in PMI than men.

4.3 STUDY III

The mean number of SA/DP net days per year increased in Y_{+1}, and remained at a higher level throughout the years of follow-up after the crash, compared with the years before the crash. While the SA/DP days increased also in the group with injuries not resulting in PMI, this increase was nowhere near that of the group with injuries resulting in PMI (Figure 6). Among those with injuries resulting in PMI, the difference in days was 8 to 11-fold (Y_{-1}: 15, Y_{+1}: 114) between Y_{-1} and each year Y_{+1} to Y_{+4}. The increase in total days among those with PMI was in Y_{+1} and Y_{+2} constituted mainly by SA days in injury diagnoses and musculoskeletal disorders. In year Y_{+3} and Y_{+4}, DP days, mainly with injury diagnoses and musculoskeletal disorders, increased. In Y_{+4} DP days constituted half of the mean days SA/DP.

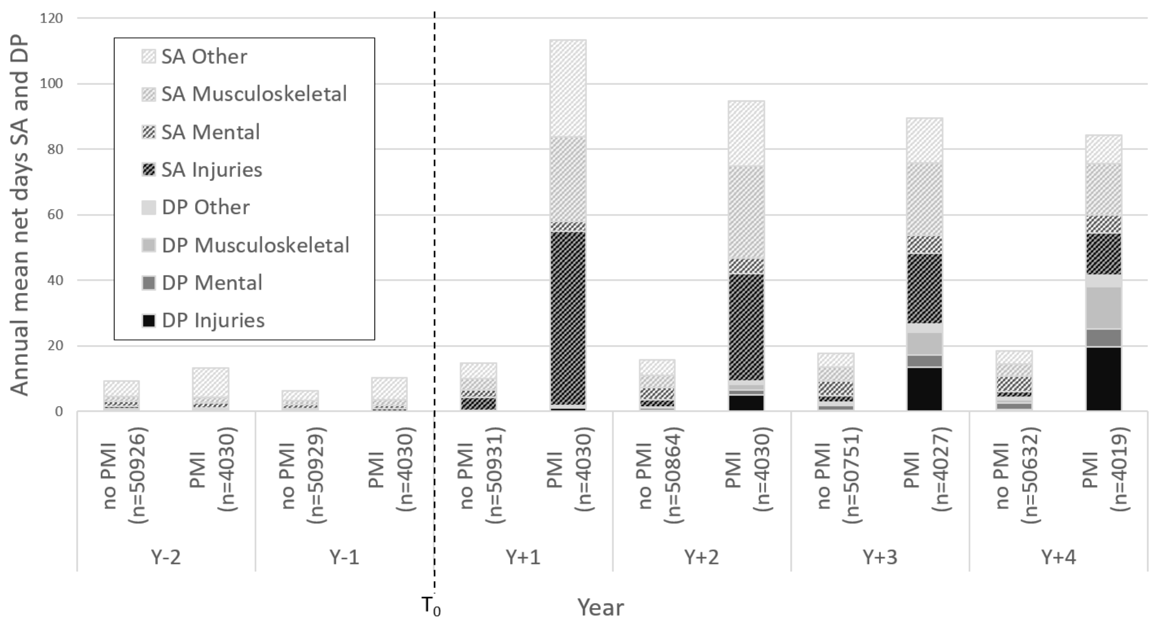

Figure 6. Mean annual number of net days of sickness absence (SA) and disability pension (DP), among 55497 individuals not already on ongoing SA/DP at the crash date (T_0), for the period Y_{+1}-Y_{+4}. Stratified on permanent medical impairment (PMI) due to injuries or not. The number of individuals differ between years due to events of immigration, emigration, or death.

Individuals with injuries to the torso/back (including WAD as well as spinal injuries), and those with multiple injuries had the highest mean number of SA/DP days in the years after the crash. In logistic regression analyses, statistically significant associations with >90 days SA/DP peryear for injury categories torso/back were found in both Y_{+2} (90-180 days SA/DP OR: 1.7; 95% CI: 1.3-2.3 and >180 days OR: 2.9; 95% CI: 2.4-3.6) and in Y_{+4} (90-180 days SA/DP OR: 2.1; 95% CI: 1.5-2.8 and >180 days OR: 2.0; 95% CI: 1.6-2.4), compared to the reference category of head injury. Multiple injuries were also associated with higher SA/DP in both years, although the ORs were generally lower than that of torso/back. The general safety level of the car, which in Study II was associated with DP after the crash, was in Study

III also found associated with future SA/DP in terms of net days per year. Occupants injured in cars with an older MYI were more likely to have >180 days SA/DP in both Y+2 (MYI ≤1993 OR: 3.3; 95% CI: 2.3-4.6) and Y+4 (MYI ≤1993 OR: 3.2; 95% CI: 2.3-4.5), compared to occupants in cars with MYI 2004-2008. Occupants in cars with a Euro NCAP star rating of 2-3 stars were more likely to have >180 days SA/DP in Y+4 (OR: 1.4; 95% CI: 1.2-1.7), compared to occupants injured in cars rated 4-5 stars.

4.4 STUDY IV

Among front seat car occupants reporting WAD after a rear-end crash, 18% of the women had symptoms lasting >4 weeks (long-term WAD), and 12% had WAD resulting in PMI. Among the men, these proportions were 13% and 9% respectively. The mean number of net SA/DP days increased after the crash among those with long-term WAD, both in total and with WAD diagnoses (Figure 7). The first year after the crash, the mean number of days among those with a long-term WAD was for the women 84 and for the men 86. The number decreased somewhat during year two and three after the crash, but remained on a level much higher than both before the crash and compared to those with no long-term WAD. Twelve percent among the women and 8% among the men had >90 days of total SA/DP in Y+2, while 1% among both women and men had >90 days of SA/DP with WAD diagnoses.

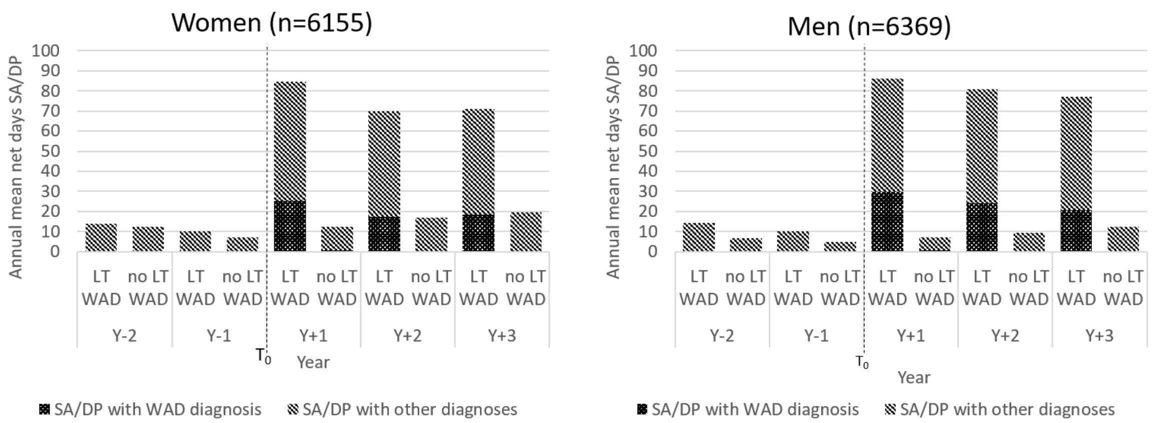

Figure 7. Mean number of net days of sickness absence (SA) and disability pension (DP) per year, among individuals not already on ongoing SA/DP at the crash (T_0). Calculated for a period of two years before and three years after the crash Y_{+1}-Y_{+3}, and for SA/DP due to WAD and other SA/DP diagnoses. Stratified by long-term WAD (LT WAD), for women and men respectively.

Out of those with long-term WAD, 67% among both women and men also had WAD resulting in PMI. Among women with PMI, the grade ranged between 1 and 20%, among men 1 to 16%. The mean PMI grade was 4% among both women and men. The SA/DP after the crash among individuals with PMI increased in a similar manner as compared to those with long-term WAD, although to a higher number of mean net days (Figure 8).

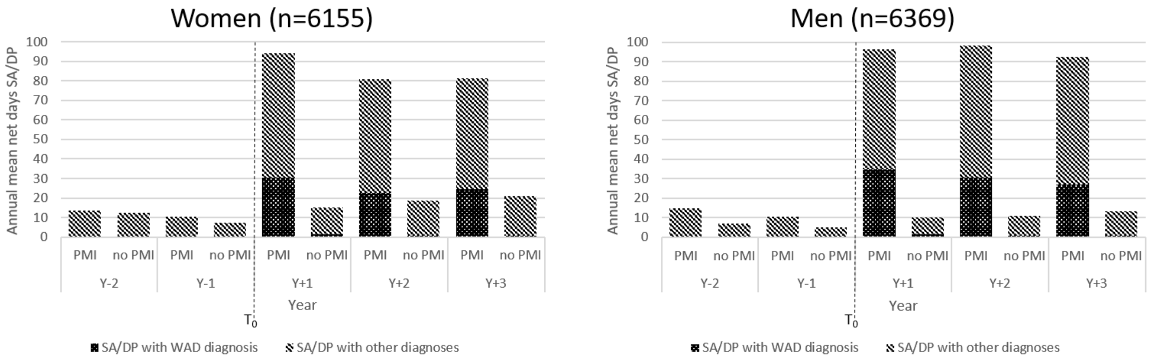

Figure 8. Mean number of net days of sickness absence (SA) and disability pension (DP) per year, among individuals not already on ongoing SA/DP at the crash (T_0). Calculated for a period of two years before and three years after the crash Y_{+1}-Y_{+3}, and for SA/DP due to WAD and other SA/DP diagnoses. Stratified by PMI ≥1%, for women and men, respectively.

Around half of both women and men with previous SA, defined as >90 days SA in Y_{-1}, had >90 days SA/DP in Y+2, compared to 9% of women and 6% of men with ≤90 days SA in Y_{-1}. Furthermore, 11% of women and 7% of men had already ongoing DP at the crash.

Among men, the number of SA/DP days due to WAD was lower among occupants of cars equipped with a whiplash protection system compared to occupants in cars without a system. The difference between cars without a whiplash protection system of older (<1998) and newer (≥1998) MYI was less prominent. Among women, the biggest differences were instead found between old and new cars, regardless of whether they were equipped with a whiplash protection system or not. This was reflected in the regression analysis. Among women, occupants in older cars were more likely to have long-term WAD (OR: 1.8; 95% CI: 1.5-2.2) and PMI (OR: 1.4; 95% CI: 1.1-1.8) compared to occupants in cars with whiplash protection systems. Occupants in newer cars without system were, however, not statistically significant more likely to have either long-term WAD or PMI.

Among men, occupants in cars equipped with whiplash protection systems were less likely to have a long-term WAD compared to occupants in both older (OR: 2.2; 95% CI: 1.7-2.8) and newer (OR: 1.6; 95% CI: 1.2-2.0) cars without whiplash protection system. Similar associations were found for PMI. Among men, occupants in cars with some of the specific systems, Toyota's passive system (PAS_TO) (long-term WAD: OR: 0.4; 95% CI: 0.3-0.7 and PMI: OR: 0.4; 95% CI: 0.2-0.8) and SAAB´s reactive head restraint (RHR_SAHR) (long-term WAD: OR: 0.4; 95% CI: 0.2-0.8 and PMI: OR: 0.2; 95% CI: 0.1-0.8), were less likely to have long-term WAD and PMI, compared to newer cars with standard seats without a whiplash protection system. Among women, no such statistically significant associations between specific systems and long-term WAD and PMI were found. Among men, occupants in older cars without whiplash protection systems were more likely to have >90 days SA/DP two years after the crash compared to those in cars with systems (OR: 1.8; 95% CI: 1.2-2.6). No statistically significant associations between different seat design and SA/DP were found among women.

5 DISCUSSION

The results showed that a tenth (10%) of individuals receiving inpatient or specialized outpatient healthcare due to a car crash had a new SA spell >14 days in direct relation to the crash, while a smaller proportion (2%) with injury reported to Folksam had a new DP two years after the crash. It was found that the mean annual net days of SA/DP increased substantially after the crash among occupants with injuries resulting in PMI, as well as among occupants with a long-term WAD (symptoms >4 weeks). In these groups, the number of SA/DP days remained on a high level for several years after the crash. In the cohort of Study III, when studying all injuries, SA/DP increased after the crash, not only SA/DP with injury diagnoses but also with musculoskeletal and mental diagnoses. In Study II, logistic regression analysis showed an association between PMI and new DP after the crash, where occupants were more likely to have a new DP with increasing PMI grade. The general safety level of the car (in terms of MY/MYI and Euro NCAP star rating) was also found to be associated with SA and DP, with occupants in older or lower rated cars being more likely to have DP and higher number of SA/DP days after the crash compared to occupants in newer or higher rated cars.

5.1 MAIN FINDINGS

Among all individuals receiving specialised healthcare in Sweden due to injuries sustained as car occupants in crashes 2010, 898 (10%) had a new SA spell >14 days following the crash, which can be compared to the findings of previous research. Two previous studies investigating incident SA for all types of injuries and severity among individuals injured in vehicle accidents and treated in hospital showed higher SA rates. These studies also included short-term SA (SA spells ≤14 days) and already ongoing SA[98, 99]. In general, the majority of SA spells are short-term, about half of all SA spells have ended within seven days and only about 2% become longer than 90 days[100, 101], which may explain the higher rates of the two previous studies. When Study III investigated SA/DP diagnoses it was found that an increase of SA/DP days mainly due to SA/DP with injury, musculoskeletal, and mental diagnoses occurs the year following the crash. The number of SA/DP days remained on a higher level than before the crash during the four years of follow-up, although there was a shift in days from SA to DP. Thereby, SA/DP following a crash is not unusual and should be addressed in order to mitigate the problems to the individual and the society that it brings. Furthermore, this calls attention to that, when studying work incapacity over a period of several years after a crash, not only SA but also DP (or the equivalent) must be taken into consideration. Otherwise the transition from SA to DP will be ignored and the results will be grossly underestimated in terms of duration, and also to some extent, in terms of incidence.

In Study I, the most common injury type was sprain of the cervical spine, which includes mainly WADs. These injuries are classified as minor injuries (AIS 1)[45] and risk being neglected when prioritizing injuries with higher AIS scores[40]. The proportion with this injury type was still lower than compared with insurance data[48, 52], which suggests that many occupants with WAD injuries do not seek inpatient or specialized outpatient healthcare after the crash. In Study I, sprain of the cervical spine was also the injury type where the lowest proportion had a new SA in direct relation to the crash. However, in Study IV, when calculating net days of SA/DP in a cohort of occupants reporting WAD after a crash, it was found that among those with a long-term WAD (symptoms >4 weeks) as well as those with WAD resulting in PMI, the mean SA/DP days were substantially increased the year following the crash. It then remained on a high level during the three-year follow-up. This indicates that looking only at incidence and duration of the first SA spell starting at the crash will not capture the full magnitude of SA/DP after a crash.

Historically, road safety targets have often been defined in terms of deaths and severe injuries reported by the police. However, the EU has for the first time set a target for reducing serious injuries within the road transport system. The number of serious injuries (MAIS3+) in the EU should be halved by 2030 from a 2020 baseline[102]. By using the MAIS3+ as the threshold, which has also been suggested by The International Traffic Safety Data and Analysis Group (IRTAD)[46], WADs are not considered a serious injury. However, by using the Swedish definition of serious injuries defined as injuries with a risk of PMI, WAD will be included. This clearly illustrates that the definition of injury outcome could have a direct link to the countermeasures prioritized. As such they would not be included in policies and preventive interventions, despite a relatively high proportion resulting in PMI and SA/DP, as can also be seen in Study IV. Furthermore, WADs constitute nearly half of injuries sustained by car occupants injured in a crash[48, 52], and more than 50% of injuries resulting in PMI[43, 53]. The results of this thesis support the suggestion that the definitions of serious injury should not only reflect initial severity (e.g., MAIS 3+, MAIS 2+) but also injuries that often lead to long-term consequences[40]. In Sweden, the definition of serious injury as those injuries resulting in PMI does capture WAD and other minor injuries resulting in long-term consequences and future situations like SA/DP. It is of importance to study the future situation also among those with other minor injuries in terms of SA/DP, to aid the prioritization of preventive strategies. These results exemplify how investigating the future situation of injured car occupants, in terms of SA and DP, contributes to generating important knowledge regarding road traffic injuries. This knowledge may then inform policy makers on which injuries to prioritise in order to achieve road safety targets as well as the SDGs of Agenda 2030.

In Study III, the mean number of SA/DP days increased after the crash, in SA/DP injury diagnoses which would be expected in a cohort of injured car occupants, but also in musculoskeletal disorders and mental diagnoses. Somatic and mental health status prior to a motor vehicle crash, has been reported as predictors of late return to work after the crash[103-105]. It has also been found to be associated with the development and recovery from WAD[106, 107]. It is possible that injuries from a car crash have an impact on SA/DP due to aggravating pre-existing disorders. Being injured in a car crash may also have later effects in terms of mental disorders[108]. Further research is required to understand the mechanisms involved, in order to increase the basis of knowledge, which could subsequently contribute to the development of preventive measures.

In the cohort using insurance data (Study II-IV), in total 8% resulted in PMI. In the subset of individuals with WAD 12% resulted in PMI. This approximately corresponds to almost 2000 individuals with injuries resulting in PMI on average per year in Sweden during the study period (2001-2013), based on the assumptions that Folksam has a 20% market share (Study II: (5035/13)/0.2=1937). Furthermore, close to 600 per year with WAD resulting in PMI (Study IV: (1508/13)/0.2=580).

5.1.1 Associations between permanent medical impairment and sickness absence/disability pension

The aim with the Swedish definition of serious injuries is to reflect health loss in terms of long-term consequences of injuries. This thesis adds a new perspective of health loss after a car crash by examining the short- and long-term situation in terms of SA, DP, and PMI. Furthermore, the associations between PMI, and SA and DP after the crash were studied. In Study III, among those with all types of injuries, and in Study IV among those with WAD specifically, the mean number of days/year with SA/DP after the crash increased extensively among those with PMI, while the difference in SA/DP before and after the crash was more modest among those without PMI. Among occupants not already on DP at the time of the crash in Study II, one out of ten occupants had been granted DP two years after the crash already at PMI 1-4%. This proportion increased with higher PMI, among those with PMI ≥20% three in four were granted DP. The association between PMI and DP was confirmed in multivariable logistic regression. These findings suggest that PMI to a large extent reflect the future situation of car occupants injured in crashes, in terms of incapacity to work. Only two previous studies have examined the association between PMI and future SA and DP among those injured in road traffic accidents. Björnstig et al. reported that among a sample of hospital patients treated for injuries sustained in vehicle-related accidents, including also non-road traffic accidents, all vehicle types and all road users (28% were car occupants), 3% resulted in PMI[88]. Among those with PMI, 14% had been granted a DP or were still on full- or part-time SA five years after the injury. Holm et al. found that in a population of individuals with PMI ≥10%, those with PMI >15% were more likely to have DP than those with PMI 10-14%[87]. Further comparisons between the results of the two previous studies and this thesis are hard due to the differences in study populations. Another complicating factor is the difference in time between inclusion to the studies, since changes in the assessment practice of PMI have occurred over the years[53]. However, an association between PMI and SA and DP can be inferred and highlight the need of preventing injuries resulting in PMI (especially injuries resulting in high PMI since these individuals will have high risk of work incapacity).

The findings of this thesis can be used in discussions whether the definition of serious injury used in Sweden (PMI ≥1%) reflects health lost. Furthermore, this can be discussed in the light of which implications the use of another grade, e.g., the definition of very serious injury (PMI ≥10%) or the use of MAIS 3+ would have. In Study II, individuals with injuries resulting in PMI 1-4% were four times more likely to be on DP two years after the crash, compared to those with no PMI, while those with a PMI ≥5% were 27 times more likely. As mentioned above, among those not already on DP at the time of the crash, the proportion of individuals with DP at follow-up increased with increasing PMI. The proportion of injured occupants on DP two years after the crash was 10% among occupants with PMI 1-4%, 23% among occupants with PMI 5-9%, 46% among occupants with PMI 10-19% and 76% among occupants with PMI ≥20%. In general, nine out of ten car occupants that sustained PMI have a PMI below 10%[52]. A similar distribution was found in the present thesis. Among those with PMI, the median PMI grade was 4%. The mean PMI among those with WAD resulting in PMI was also 4%, which means that with a ≥10% or even a ≥5% cut-off, most WAD injuries would not be included, and the road traffic safety problem they constitute would be underestimated. Furthermore, in study III and IV, substantial differences in mean SA/DP days per year after the crash were seen between those with PMI compared to those with no PMI. From the perspective of work capacity, a low proportion of injured occupants with PMI of ≥1% would have a DP two years after the crash, but in that group the mean number of SA/DP days would be high. Furthermore, as seen in Study III, in the group with PMI ≥1%, SA/DP days with DP diagnoses increases mainly in year three and four after the crash. In terms of net days SA/DP, a threshold of PMI ≥1% seems to capture a majority of the increase in SA and DP due to injury after a car crash, and could from that perspective be recommended as a target for policy and action to prevent such consequences. Regarding MAIS 3+, Rissanen et al. has shown that road traffic injuries classified MAIS 3+ resulted in a higher number of SA days immediately after the crash which is then more quickly reduced, compared to less severe injuries[109]. This can be compared to the findings regarding WAD (an injury classified as AIS 1) in this thesis. Only 5% of car occupants receiving inpatient or specialized outpatient healthcare due to WAD after a crash had a new SA spell in relation to the crash. However, among those reporting WAD to Folksam, 10% had a WAD resulting in PMI, and in this group the number of SA/DP days remained high throughout the three-year follow-up (Figure 8). This indicates that the PMI ≥1% threshold can present a very different picture of the consequences of serious injuries in the road transport system compared to MAIS 3+.

5.1.2 Improvements of the road transport system

According to the Safe System Approach the focus is on shared responsibility between system providers and road users in order to reduce injuries within the transport system[110]. As long as the road user obeys traffic rules, the system providers must, according to Vision Zero, establish that the system is safe to use. These could be the stakeholders providing safe roads, car manufacturers providing safe vehicles, and healthcare services providing timely and adequate healthcare to those injured in crashes. An example of this is that many new vehicle safety technologies have partly shifted the responsibility from the driver to the vehicle (e.g. seat belt reminders, alcohol interlock etc) or the road design (e.g. roundabouts and midseparated roads) which has increased the safety level of the system.

As mentioned in section 1.2.3, car safety has been greatly improved during the last decades[54]. Additional technologies still to be implemented on a larger scale, such as speed limiters and geofencing, also show promise of further improving the safety within the road transport system. New technologies, such as Autonomous Emergency Braking with pedestrian and cyclist detection, also have the potential to reduce the risk of injury among unprotected road users[64]. This thesis show that the overall car safety based on Euro NCAP star rating (Study III) and in terms of MY/MYI (Study II-IV) is associated with SA, DP, PMI and long-term WAD after the crash. Previous studies have also shown that standardised consumer crash tests such as Euro NCAP have led to significant improvements in vehicle crashworthiness[111-113].

In Study IV the associations between advanced whiplash protection systems and long-term WAD, PMI and SA/DP were studied. The results of this thesis, as well as the results from previous literature indicate that car safety performance is an important factor of reducing consequences of road traffic injuries. This suggests that great benefits could be achieved by improving the safety level of the vehicle fleet. The aim of this thesis was to generate knowledge on the future situation of those injured, in terms of SA, DP and PMI, and not to study effects of different interventions. However, several interventions could be supported by the results. For example, improving the overall safety level of vehicle fleet would decrease SA, DP and PMI. This could be achieved, e.g., through car safety requirements in purchase policies of corporate and government organisations. Scrapping schemes would reduce the long-term consequences by reducing the number of older cars.

In Sweden, the mean age of the vehicle fleet is high, in 2012 12% were older than 17 years[114]. Because of this, it will take a long time until the relevant, potentially effective vehicle safety technologies will be widely spread. An improved implementation of these technologies could be achieved through scrappage programs or other incentives for upgrading the car fleet. Scrapping old cars with lower safety standards have been shown to have a large potential to prevent injuries resulting in PMI ≥1% and to be cost-effective[115]. This thesis has shown that SA/DP after a crash was higher among occupants injured in old cars, as well as among occupants with injuries resulting in PMI. It can be assumed that scrapping older cars would also have the benefit of reduced SA/DP among those injured. Furthermore, it could be the case that old cars are often purchased and driven by a driver population with a lower seat belt usage and different driver behaviour, and therefore are more often involved in severe crashes where the non-use of seat belt is a critical factor. Stigson and Hill showed that drivers of older cars more frequently violate several regulations concurrently[116]. These factors could strengthen the potential benefits of interventions to improve the implementation of safety technology. In an international perspective, scrapping schemes may be most effective to achieve overall higher vehicle fleet safety in countries with a vehicle fleet of high mean age, such as Sweden. However, the safety standard of the Swedish vehicle fleet is high, which could mean higher potential of scrapping old cars in other countries with lower fleet safety, if they are replaced by cars with high implementation of safety technology.

Information to purchasers has been suggested as an important tool to improve vehicle fleet safety[16]. Corporate organisations and government at different levels, could in their policies specify requirements on the safety performance of vehicles into their fleets. This would improve the health of the workforce, which would further support all other targets of SDG 3, to ensure healthy lives and promote well-being for all at all ages[117]. The findings of this thesis suggest that this would also translate into reduced SA and DP due to road traffic injury in the workforce of these organisations.

Based on the findings in Study IV and previous literature, that seat design has different influences on the consequences for women and men in a crash, policies on the purchase of vehicles should include a gender equality aspect, where existing safety technology should benefit all, that is, both women and men of all ages. Furthermore, as system providers in the road transport system, car manufacturers have the responsibility to provide cars that will not lead to unacceptable health loss, and thus, they should take actions regarding this. To develop whiplash protection systems that are efficient for women is especially important in the perspective of SA/DP, since women both have a higher risk of WAD[52, 70] and higher risk of SA/DP in general[82].

This would also have an effect on other sustainable development goals, e.g., in terms of improved air quality and reduced emissions. Agenda 2030 states that the SDGs are "integrated and indivisible"[14], and the international Council for Science has highlighted synergistic effects between goal 3 and other SDGs[117]. Therefore, crash or injury prevention is not limited to actions specifically aimed to improve the road safety, but could be achieved through synergies with activities to achieve other SDGs.

The studies in this thesis do not consider the safety level of the road. However, during the last decades, improvements of the road transport system have been achieved, e.g., median- and side barriers and roundabouts have been implemented in a systematic way in Sweden and studies have shown a reduction in crash severity[118, 119]. Furthermore, speed limits based on the Vision Zero were adopted in Sweden in 2008. These improvements may have influenced the results of this thesis. The healthcare available to those injured in crashes over the years have also developed. Another aspect influencing road traffic injury is the economy, e.g., a reduction in the number of road traffic fatalities with increased fuel price have been found[120]. Information on these factors were not available for the cohorts, which might be considered as limitations. However, these factors were not in the scope of this thesis, and thus further studies would be required to assess their association with SA/DP and PMI.

5.1.3 Sickness absence and disability pension prior to the crash

Sickness absence and/or DP after the crash were more common among individuals with previous SA or DP before the crash, as seen in Study II and IV. In cases with long-term work incapacity due to the injury, a transition from SA into DP is expected. In Study II, SA starting at the crash and still ongoing at follow-up (>2 years) was defined as DP. In the regression analysis, where those already on DP were excluded, already ongoing SA at the date of the crash was the factor with the strongest association with DP at follow-up. Also in line with this expectation, in Study III the increase in SA/DP days in the years after the crash was constituted mainly by SA in the first two years and by DP in year three and four of the follow-up.

In Study IV, a higher proportion of individuals with previous SA, defined as >90 days of SA/DP in the year before the crash, had long-term WAD, PMI due to WAD, as well as >90 days of SA/DP in the second year following the crash, compared to those with ≤90 days. There might be several explanations for this association, e.g., a decrease of work capacity due to worsening of existing medical conditions, or a vulnerability for consequences of road traffic-related injuries. Interventions to increase the safety of the car and road by reducing crash severity may particularly benefit groups with low tolerance to crash forces. It could also be argued that improvements in tertiary prevention, such as the post-crash healthcare treatment and rehabilitation would benefit these groups. Due to a high prevalence of SA and DP in the general population, future studies are required to clarify these associations and how consequences of injuries from car crashes can be prevented or mitigated in this group. To compare the prevalence of already ongoing SA and DP at the time of the crash in this thesis with that of the general population would require the use of matched references. To make such comparisons were not in the scope of this thesis. That some already were on SA at the time of the crash illustrates the presence of such severe morbidity that it leads to work incapacity already prior to the crash. As mentioned in section 5.1, health status prior to a crash has been found to be associated with return to work after the crash. A previous study found self-reported pre-injury chronic disease to be associated with not having returned to work two years after sustaining an injury in a motor vehicle crash[104], while only one of two studies on the association between self-assessed pre-injury health and return to work after a motor vehicle crash showed an association[103, 104]. Among individuals with WAD, neck disability prior to the crash has been found associated with prolonged recovery[121], and individuals with granted compensation for loss of earnings due to the WAD have been found to use more healthcare the year prior to the injury, compared to individuals with no granted compensation[122]. However, very few studies include SA and DP prior to the crash when studying consequences of road traffic injury. One study of individuals with WAD found that a SA prior to the crash was associated with both considerable neck pain and a negative change in provisional status, defined as going from self-supporting or unemployed to temporary or permanent health-related benefits, or going from temporary to permanent health-related benefits, one year after the crash[123]. Another study found that SA but not DP prior to the crash was associated with subsequent chronic WAD[106]. The results of this thesis together with these previous studies clearly show that previous SA and/or ongoing SA and DP at the crash, should be considered when studying consequences of road traffic injury, or the results will be heavily affected.

5.1.4 Sociodemographic factors

In Study I and II, sociodemographic factors were found to be associated with SA and DP. The proportions of individuals with new SA following the crash increased with age, and the ORs of having a DP at follow-up was higher with increasing age. The risk of being injured in motor vehicle crashes has been found higher in general among those of older age in many studies[65, 124-126]. Older individuals have also been shown to have lower functioning and health after a crash[127], and individuals with a slow decrease of gross SA days in the period after a crash are more often older than those with a quicker decrease[109]. Although, some specific injury types can have more severe consequences among younger age groups. For example, WAD has the highest RPMI on the 1% level in ages 20-44 among women, and in ages 45-59 among men[52]. Higher age has also been associated with work incapacity after road traffic injury[128-131]. In Study II, occupants aged 45-64 were almost three times, and those aged 55-62 almost four times, more likely to be on DP two years after injury as the reference group of those 17-24 years old. In the older age group (45-64 years old) in Study I, injuries to the spine and spinal cord, and traumatic brain injuries of other type than concussions stand out especially, with very high ORs for SA following the crash, compared to the reference category sprains of the cervical spine. A previous study has shown that car occupants ≥46 years old have higher risk of AIS2+ spinal injuries[132]. With an ageing population, these injuries will be increasingly common in future years if no intervention is implemented, which addresses them. Furthermore, these injuries have not decreased over the recent decades, but rather remained on a similar frequency[67] or even increased[133]. This warrants further studies on consequences of spinal injuries in this age group, and how to effectively prevent them. As can be seen in Figure 2, improved car safety over the last decades have reduced the risk of head injuries substantially, while the risk of injuries to the spine have not seen a similar reduction. Effective car safety systems and road infrastructure that reduce the risk of spinal injuries, also have the potential to address the future situation in terms of reduced SA especially in the older part of the working population. Few examples of car safety systems that target spinal injuries currently exist[134] and actions on addressing these are needed.

Furthermore, individuals with lower education were more likely to have a new SA spell following the crash, to be on DP two years after the crash, as well as having injuries resulting in PMI, compared to those with college or university education. An exception was individuals aged 16-44 with elementary school as their highest educational level; they were less likely to have a new SA spell following the crash. This exception from the trend may be due to that a lower proportion in this group have passed from education to paid work, thus the proportion eligible for SA would be lower. Education level is in this thesis used as a proxy for socioeconomic situation. There may be many reasons for the associations between low educational level and SA/DP. Previous studies have however shown that lower educational levels are associated with higher risks of being injured in car crashes[135, 136]. One explanation to this could be that socioeconomic situation could be correlated to both the safety level of and MYI of one’s car. Previous studies of return to work after injuries from motor vehicle crashes, have presented heterogeneous results regarding the associations with education and occupation, where some studies have found an association[103, 137, 138], and others have not[104, 139]. Identifying groups at risk is important for targeting interventions that could prevent serious injury, and for adopting just and effective insurance compensation policy. However, more knowledge is warranted to clarify the associations between factors related to education, income and SA/DP.

5.2 METHODOLOGICAL CONSIDERATIONS

There are several strengths and limitations of the four studies. Main strengths are the use of large datasets; of high-quality nationwide register data where microdata could also be linked at individual level from the different registers, the large materials allowing for sub-group analyses, that a large number of factors could be included in the analyses (sociodemographics, injury- and car-related factors, SA, DP, PMI, etc.), having detailed information on both SA and DP as well as on the crash and the injuries sustained, that the cohorts could be restricted to those of working age, and that those who died or emigrated during follow-up could be excluded from the years not alive or not residing in Sweden, and that the analyses of SA and DP could be based on crash date, rather than on e.g., calendar year. Other strengths were that net days of SA and DP could be calculated and used in the analyses, instead of gross days, and that the same definition of DP as used by OECD[79] and by others[140] could be used in order to facilitate international comparisons. The latter is important as in most countries there is a limitation to number of days a SA spell can continue – often the limit is one year, while in Sweden it is possible to be on SA for several years.

Initial injury diagnoses were in Study I and III categorised according to a modified version of the Barell matrix[96]. The strengths of using this method are that injuries could be characterized by body region and nature of injury, and then be merged into a feasible number of categories with a relevant level of detail. Furthermore, the use of the matrix provided the possibility to create a uniform categorisation of diagnoses from different classification systems, AIS and ICD, used in Study III and enabled comparison between initial injury diagnoses and SA/DP diagnoses.

The studies in this thesis, like all studies, had limitations. These include, e.g., not having access to primary healthcare information, not having information on SA spells ≤14 days, the selection of one injury per individual in two of the studies, uncertain crash date in study I, possible subsequent injury or morbidity during the follow-up period which could affect future SA and DP, missing information for some variables, possible selection bias through use of data from one insurance company, and potential residual confounding. These are discussed below.

One of the limitations is that information on visits in primary healthcare was not available, which means that there might be an underestimation of the number of injured car occupants in Study I. If diagnoses from primary healthcare had been available, probably more minor injuries could have been included in the logistic regression analyses of study III. However, Study II and IV included all injuries reported to Folksam regardless of injury severity. In

Study III injuries were included regardless of severity in the analyses of SA/DP days per year. Since the motor vehicle insurance is mandatory, this renders claims data representative of all injured. Furthermore, using insurance data made it possible to examine the whole spectrum of injuries, also those cases where the injured individuals did not visit healthcare services.

Type of occupation of the injured person might be associated with future SA and DP, however, such information was not obtained for the thesis. How occupation has been measured and categorised differs between previous studies, and results are heterogeneous. Some studies have found occupational factors related to work capacity after a crash[103, 128, 137, 141], while others have not[104, 129, 139]. Investigating the association between occupational factors and SA/DP and PMI was not in the scope of this thesis but needs to be elucidated by future studies. Instead, level of education was used as a proxy for socioeconomic situation.

It can be seen as both a limitation and strength that data about shorter SA spells, not lasting more than 14 days, could not be included. This means that short SA spells due to, e.g., upper respiratory infections, stomach flu, asthma, etcetera, were not included. Shorter SA spells due to injuries from the car crash are, however, not reflected.

Validity

The main strengths of the four studies relate to the use of high quality Swedish nationwide register data[142, 143], which strengthens the validity of the studies in several ways. The validity of a study pertains to the accurateness of the inferences that are being made, either regarding the population that the inferences concern (internal validity) or how the inferences can be generalized to the general or other populations (external validity)[144]. The main factors influencing the internal validity are confounding, selection bias, and information bias.

Selection bias occurs when the procedure used to select participants creates a selection that is not representative of those theoretically eligible for participation, regarding the relation between exposure and outcome[144]. The studies in this thesis include all eligible (regarding age, year of crash etc.) individuals from the respective population, which in Study I were all residents in Sweden with an inpatient or specialized outpatient visit due to a car crash, and in Study II-IV car occupants reporting injuries from crashes to Folksam. Those who died or migrated during the follow-up periods of study II and IV, respectively, were also excluded from analyses for the relevant years. This minimises the risk of selection bias.

Information bias is caused by measurement errors in the information required, which may lead to misclassification[144]. If the misclassification of a variable is dependent on other variables, it is a differential misclassification, and may lead to over- or underestimation of associations between exposure and outcome. If the misclassification is random, it is a non-differential misclassification, and may lead to a dilution of the estimate of association. By using data from high-quality registers with high coverage[95, 142, 143], the risk of misclassification was reduced. However, for some individuals, information for one or some variables was missing, or coded as unknown. The variable Crash type in Study I had a 23% proportion of cases coded as 'Unspecified traffic accident'. In study II, MY was unknown in 16.6%, and Crash impact direction in 5.4% of the cases. It is possible that having more detailed information on these cases, would have changed the estimates of the associations to a limited extent, between the respective variable and the outcomes. In Study III and IV, the proportion with unknown information on MYI was lower and would have less effect on the estimates.

The fact that these studies could identify the occupants already on SA/DP at the time of the crash is another strength in all the four studies, and is something that has rarely been done in previous studies. To have information on who that is already on SA/DP reduces the risk of misclassification, and also the selection bias since those not at risk of new SA/DP could be excluded from analyses where needed.

The outcomes of the four studies related to SA spells >14 days, DP, and PMI all have to be certified by a physician in order to be granted. The initial injury diagnoses used in Study I and III were also certified by physicians. This means that the risk of misclassification is substantially lower than if these variables were, e.g., self-reported. However, selecting only one injury diagnosis per individual, as in study I and IV, can be seen as a limitation and a potential source of misclassification. The selection process used in these studies may not have succeeded in pinpointing the diagnosis relevant for the SA. Therefore, the occurrence of multi-trauma was also studied in Study III. However, this affects only a smaller group, as the majority (79% in Study I and 81% in Study IV) had only one unique injury diagnosis.

In Study I, the exact crash date was not known. Instead, the date of the first healthcare visit due to the injuries sustained in a crash was used – which in some cases might have occurred one or a few days after the crash. To minimize misclassification of SA-status, this was handled by defining new SA as a spell starting ±4 days of the date of the healthcare visit, and ongoing SA and DP as a spells starting ≥5 days prior to the healthcare visit. These cut-offs were based on distribution of start dates in relation to the dates of the healthcare encounters in the study population. Furthermore, in order to avoid including individuals who had healthcare visits due to injuries from previous crashes, individuals treated for transportation-related injuries at any time during a period of three years prior to inclusion were excluded.

Out of all identified occupants injured between 2001-2013 in the cohort of Study II, from which Study III and IV used sub-cohorts, a small proportion (5%) had more than one crash during this period. In this study, only the first crash was included. Furthermore, those with a new crash within the follow-up of each study were excluded. This decreases the risk of DP and PMI at follow-up being due to injuries from more than one crash. However, individuals may have had subsequent crashes where they were covered by other insurance companies, as well as other morbidity that affects DP status at follow-up. To minimize this risk, the follow-up period was limited to two years in Study II, four years in Study III, and three years in Study IV.

A confounding factor affects the association between exposure and outcome. It is associated with both the exposure and the outcome, while it is not in itself an effect of either one of them, and is not a step in the causal pathway[144]. The use of linked microdata from several registers, made it possible to control for several potential confounders, such as sociodemographic and crash-related factors. It is, however, not unlikely that there exists confounding from other factors not included in the analyses. For instance, as mentioned previously, type of occupation was not controlled for. The occupation could influence both which car one is an occupant in and SA after a crash, due to job demands and adjustability of work tasks, etc.

Controlling for additional confounding factors would probably improve the accuracy of the estimates. Regarding external validity, Study I was based on the total population in Sweden, including all those receiving specialised healthcare during 2010 due to injuries from passenger car crashes. The results are thus directly applicable to the general population of working age in Sweden. In Studies II-IV, the study populations were identified from Folksam data, which is based on car crashes reported to the insurance company. Folksam has an approximately 20% market share of the mandatory road traffic insurance in Sweden[145]. The study population of Study II and III was very similar to the study population of Study I regarding the distribution of sociodemographic factors of the participants. In study II and III, the study population is somewhat older, has a higher proportion of individuals born in Europe outside of Sweden, a lower proportion born in the rest of the world, a lower proportion of married individuals, and a higher proportion already on SA/DP at the time of the crash compared to in Study I, however, those differences are relatively small. Considering the external validity of the four studies, generalization of the results to other populations can be done, while taking some factors into consideration. In a national perspective, the results of Study I can be generalized to those receiving inpatient and specialized outpatient healthcare due to injuries from car crashes, while Study II-IV includes all types of injuries and can be generalized to all those injured in car crashes. In an international perspective, additional factors must be taken into consideration, such as type of social and health insurance system and differences in labour market participation. In Sweden, the labour market participation is high among both women and men and also at higher age. Countries with a lower participation have more health selection into the labour market, where those with low health may not have paid work. Furthermore, social insurance systems differ between countries. The generalisability of the results will be the highest regarding countries with similar labour market and social insurance system structure. Furthermore, the studies included individuals of working ages. Generalisability will be difficult regarding younger and older age groups, due to anatomical differences between these groups and the studied populations.

6 CONCLUSIONS

- Out of all individuals receiving inpatient or specialized outpatient healthcare in Sweden after a car crash in 2010, 9% were already on SA/DP when the crash occured. New SA spells >14 days in direct relation to the crash is not unusual (overall incidence of 10%) among those receiving healthcare, but more likely among those with more severe injuries, such as injuries to the vertebral column and spinal cord and traumatic brain injury than among those with sprains of the cervical spine (including WAD).
- Out of all car occupants of working age injured in crashes 2001-2013, reported to Folksam, 8% had injuries resulting in PMI. This number corresponds to approximately 1900 individuals of working age annually in total in Sweden during this period. Furtermore, 2% had a new DP two years after the crash. The grade of PMI reflected the future situation of those injured in terms of higher likelihood of DP with higher PMI grade. However, the likelihood is notable already from low PMI grades (1-4%) compared to individuals without injuries resulting in PMI. Being an occupant in an older car, indicating a lower overall safety level, was associated with higher likelihood of both PMI and DP after the crash. New DP was more likely among those with already ongoing SA at the crash which indicates that neglecting to take SA prior to the crash into consideration will result in an overestimation of SA and DP following the crash.
- The mean number of SA/DP net days per year increased after the crash and remained elevated during the four year follow-up after the crash. This implies that the future situation, in terms of SA and DP, among injured car occupants needs to be studied over several years after the crash.The increase was mainly due to SA/DP with injury diagnoses, musculoskeletal diagnoses, and mental diagnoses. Occupants with injuries resulting in PMI of any grade (the definition of serious injury used in Sweden), had substantially more SA/DP days than those with injuries not resulting in PMI. This suggests that this definition of serious injury might be more useful as a target for policy and actions to also prevent SA and DP following a crash, than using a higher PMI grade would be. A high number of SA/DP days after the crash was most likely among occupants with injuries to the torso/back or with multiple injuries. Occupants in newer cars and cars with high Euro NCAP star rating were less likely to have high number of SA/DP days after the crash.
- Among front seat car occupants reporting WAD after a rear-end crash, 18% among the women and 13% among the men sustained long-term WAD (symptoms >4 weeks) and 12% among women and 9% among men had WAD resulting in PMI. This corresponds to approximately 600 individuals of working age annually in Sweden that will have such PMI. Among individuals with WAD resulting in PMI, the mean number of SA/DP days the year following the crash was high, indicating substantial difficulties for this group. These effects might be missed if only studying initial SA spells, something only 5% of the individuals with inpatient or specialized healthcare due to WAD had.
- Men reporting WAD after a rear end crash were less likely to have long-term WAD and PMI if the car they were occupants in was equipped with a whiplash protection system

compared to occupants in both older and newer cars without whiplash protection system. Women in cars with whiplash protection systems were less likely to have long-term WAD and PMI compared only to women in older cars without systems. Men in cars with systems were also less likely to have high number of SA/DP days than men in older cars without system. These results indicate that the whiplash protection systems benefitted women to less extent than men in terms of long-term WAD and PMI.

7 SUGGESTIONS FOR INTERVENTIONS AND FUTURE RESEARCH

Despite successful road traffic safety interventions in Sweden, the results in this thesis show that injuries from car crashes can result in long-term consequences in terms of PMI and affect the future situation, in terms of SA and DP, of the injured occupants.

- The influence of car seat design on long-term WAD, PMI, and SA/DP found in this thesis differed between women and men, indicating that actions are needed. Consumer tests like Euro NCAP should be further developed to reflect gender differences in future test procedures.
- The high proportion of granted DP and high number of SA/DP days per year among those with injuries resulting in PMI also shows the need to further develop interventions aimed to prevent injuries leading to long-term concequences and not only focus on preventing initial injuries.
- Improving the overall safety level of the car fleet would decrease SA, DP and PMI. This could be achieved, e.g., through car safety requirements in purchase policies of corporate and government organisations. Scrapping schemes would reduce the long-term concequences by reducing the number of older cars. This could also have an effect on other sustainable development goals, e.g, in terms of improved workforce health, improved air quality, and reduced emissions.

In this thesis four explorative studies were conducted, all showing important aspects regarding the immediate and future situation among injured car occupants. As often, the results indicate the need for future studies with more specific research questions, as well as need for specific knowledge that can be used for interventions. Below are both some recommendations for the design of future studies and what needs to be targeted in them.

- Studies of work incapacity over a period of several years following a crash, should examine not only SA but also DP, as shown by the investigation of DP, and the shift from SA to DP in the years after the crash found in this thesis. Ignoring the transition from SA to DP will result in underestimations of duration of work incapacity. Not examining DP will result in that the full extent of the future work incapacity will not be accounted for.
- As seen in this thesis, also injuries that ususally result in low PMI grade, such as WAD, may have considerable effect on the future situation of injured car occupants. To gain a more complete picture of the consequences of road traffic injuries, future studies should examine consequences in a wider perspective, e.g., include also work capacity over time.
- To better capture the full extent of SA and DP, future studies should have a prospective design with long follow-up periods and consider using multiple measures, e.g., incidence/prevalence as well as duration rather than, e.g., a point prevalence.

- Future studies should also take into account already ongoing SA/DP among injured individuals, as well as previous SA, since this might have a strong association with SA and DP following the crash.
- To study consequences of injuries sustained in car crashes, injured individuals should also be compared with matched references from the general population.
- More research is recommended in order to evaluate the performance of different safety systems, such as different types of whiplash protection systems. This should be done for women and men separately, using different outcome measures, and for both short and long follow-ups.
- With an ageing population, SA/DP after car crashes will probably increase among injured car occupants without effective countermeasures. Considering the vulnerability of older individuals and the lack of risk reduction seen for some types of injuries especially among older people over recent decades, e.g., spinal injuries, it would be of interest to study how future changes in the age distribution of injured car occupants might influence the problem picture, e.g., in terms of SA/DP among injured car occupants.

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