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# SICKNESS ABSENCE AND DISABILITY PENSION AMONG INJURED BICYCLISTS AND PEDESTRIANS

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# Sickness absence and disability pension among injured bicyclists and pedestrians
## Thesis for Doctoral Degree (Ph.D.)

By

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To the humans behind the numbers

# Abstract

**Background:** Active transportation such as walking and bicycling provides an opportunity for individuals to incorporate physical activity into daily life. It has a positive impact on public health and is an important aspect of a sustainable road transport system. However, it also involves some risks. Globally, about a fifth of all fatalities within the road transport system are represented by pedestrians, and bicyclists are the road user group with the highest number of severe injuries in the European Union. Being injured in a road traffic accident may affect the individuals' work ability and lead to sickness absence (SA) and disability pension (DP). Still, knowledge is lacking on the short- and long-term consequences of road traffic injuries among bicyclists and pedestrians in terms of SA and DP. Therefore, the aim of this thesis was to generate broader and deeper knowledge of SA and DP after a road traffic accident among injured working aged bicyclists and pedestrians.

**Method:** Five nationwide studies using Swedish register data of working-age individuals were conducted. **Study I** and **Study II** included all bicyclists injured in a road traffic accident in 2010. **Study III** and **Study IV** included all pedestrians injured in a road traffic accident (including fall accidents) in 2010 and 2014-2016, respectively. In **Study I - Study IV** SA and DP were analysed with logistic regression, sequence analysis, cluster analysis, and multinomial logistic regression. **Study V** included all working individuals injured in a road traffic accident (pedestrians, bicyclists, car occupants, and other road users) in 2015 and population-based matched references (matched on: sex, year of birth, level of education, country of birth, type of living area) without any traffic-related injury during 2014-2015. Mean SA and DP net days/year for each road traffic group and excess SA and DP net days/year compared with their matched references were calculated.

**Results:** In **Study I,** 85% of the 7643 injured bicyclists were injured in a single-bicycle crash. Among all, 10% were already on SA or full-time DP, while 18% started a new SA spell (>14 days) in connection with the crash. Women and older individuals had higher OR for new SA. The injury types with the highest ORs for new SA were fractures (8.04; 6.62–9.77) and internal injuries (7.34; 3.67–14.66), compared with external injuries. For the injured bicyclists in **Study II,** seven clusters of SA and DP were identified: "No SA or DP" (58.2% of the cohort), "Low SA or DP" (7.4%), "Immediate SA" (20.3%), "Episodic SA" (5.9%), "Long-term SA" (1.7%), "Ongoing part-time DP" (1.7%), and "Ongoing full-time DP" (4.8%). Compared to the cluster "No SA or DP", all other clusters had higher ORs for women and older age groups. The clusters "Immediate SA" and "Episodic SA" had higher ORs for fractures, whereas the cluster "Long-term SA" had higher ORs for traumatic brain injury, not including concussion (18.4; 2.2–155.2). In **Study III**, 75% of the 5576 injured pedestrians were injured in a fall accident, and half of the falls were related to snow and ice. Among the injured pedestrians, 18.3% were already on SA or full-time DP, and 20% started a new SA spell in connection with the accident. Older individuals had a higher OR for new SA. Fractures were the injury type with the highest OR for new SA when compared with the reference group external injuries (9.58; 7.39-12.43). The injured body region with the highest OR for new SA, was lower leg, ankle, foot, and other leg, compared with the reference group head, face, and neck (4.52; 2.78-7.36). For the injured pedestrians in **Study IV,** eight clusters of SA patterns were identified. The largest cluster was characterized by no SA or DP (46.7%), four clusters had different SA patterns due to injury diagnoses (immediate (17.9%), episodic (3.9%), later (3.2%), and combined with SA due to other diagnoses (7.0%)). Two clusters had SA due to other diagnoses (short-term (16.6%) and long-term (2.0%)) and one cluster mainly consisted of individuals with DP (2.7%). Compared to the cluster "No SA", all other clusters were associated with older age, hospitalized at inclusion, and working in health & social care. The clusters “Immediate SA”, “Episodic SA” and “Both SA due to injury and other diagnoses” were also associated with sustaining a fracture. In **Study V** a third of the individuals injured in a road traffic accident were bicyclists, 31% car occupants, 16% pedestrians, and 19% were other road users (mostly motorcyclists and mopeds). Pedestrians and other road users were the road user groups with the highest mean number of SA days during the first year following the accident (51 and 49 days/year respectively). The matched references had between 8 and 13 SA days/year throughout the study period. The excess SA days/year was elevated for all road user groups the whole study period. Excess SA due to injury diagnoses was 15-35 days/year during the first year following the accident. Excess SA due to diagnoses other than injuries were about eight days/year for pedestrians and car occupants during the whole study period and about zero for the bicyclists. The excess DP was low, although it increased every year for pedestrians and for car occupants; for bicyclists no excess DP was observed.

**Conclusions:** This thesis showed that both among injured bicyclists and pedestrians, about a fifth had new SA in connection with the accident. In addition, both groups had excess SA during the following years after the accident compared to their references. However, bicyclists’ excess SA and DP decreased faster after the accident than the pedestrians’. Fractures were associated with SA in connection with the accident for both pedestrians and bicyclists, and traumatic brain injury was associated with long-term SA for bicyclists.

# Svensk sammanfattning

**Bakgrund:**
Att gå eller cykla ger möjlighet att utföra fysisk aktivitet i vardagen. Det har en positiv inverkan på folkhälsan och är en viktig del av ett hållbart transportsystem. Men det medför också vissa risker. Fotgängare representerar globalt en femtedel av alla dödsfall inom vägtransportsystemet, och cyklister är den trafikantgrupp som har flest allvarliga skador i Europeiska unionen. Att bli skadad i en trafikolycka kan påverka individens arbetsförmåga och leda till sjukskrivning och sjuk- och aktivitetsersättning (hädanefter kallat sjukfrånvaro). Kunskap saknas om konsekvenserna av trafikskador bland cyklister och fotgängare vad gäller sjukfrånvaro. Syftet med denna avhandling var därför att bredda och fördjupa kunskapen om sjukfrånvaro efter en trafikolycka bland skadade cyklister och fotgängare i arbetsför ålder.

**Metod:**
Fem studier med rikstäckande registerdata över individer i arbetsför ålder genomfördes. **Studie I** och **Studie II** inkluderade alla cyklister skadade i trafikolyckor 2010. **Studie III** och **Studie IV** inkluderade alla fotgängare skadade i trafikmiljö (inklusive fallolyckor) 2010 respektive 2014–2016. I **Studie I - Studie IV** analyserades sjukfrånvaron med logistisk regression, sekvensanalys, klusteranalys och multinominal logistisk regression. **Studie V** inkluderade alla arbetande individer skadade i trafiken (fotgängare, cyklister, bilister och övriga trafikanter) 2015 och matchade referenser (matchade på: kön, födelseår, utbildningsnivå, födelseland, och boenderegion) utan trafikrelaterade skador under 2014–2015. Medelantalet dagar med sjukfrånvaro per år (för fem år) för varje vägtrafikantgrupp samt genomsnittlig skillnad (överskott) av dagar med sjukfrånvaro per år jämfört med de matchade referenserna beräknades.

**Resultat:**
I **Studie I** skadades 85 % av de 7643 cyklisterna i en singelolycka. Totalt hade 10 % redan pågående sjukfrånvaro, medan 18 % startade ny sjukskrivning i samband med olyckan. Kvinnor och äldre hade högre oddskvot (OR) för ny sjukskrivning. Personskadorna med högst OR för ny sjukskrivning var frakturer och inre skador.
I **Studie II** identifierades sju kluster av sjukfrånvaromönster: två med lite eller ingen sjukfrånvaro, tre med olika mönster av sjukskrivning (Omedelbar, Episodisk och Långtidssjukskrivning) och två med olika omfattning av sjuk- och aktivitetsersättning (deltid, heltid). Klustren "Omedelbar sjukskrivning" och "Episodisk sjukskrivning" hade högre OR för frakturer. Klustret "Långtidssjukskrivning" hade högre OR för traumatisk hjärnskada (ej inkluderat hjärnskakning).
I **Studie III** skadades 75 % av de 5576 fotgängarna i en fallolycka, hälften av dessa fall var relaterade till snö och is. Totalt hade 18 % redan sjukfrånvaro vid olyckan, medan 20 % påbörjade en ny sjukskrivning. Personskadorna med högst OR för ny sjukskrivning var frakturer. Den skadade kroppsregionen med den högsta OR för ny sjukskrivning var underben, fotled och fot.
I **Studie IV** identifierades åtta kluster av sjukfrånvaromönster. Det största klustret var ”Ingen sjukfrånvaro”, fyra kluster hade olika sjukskrivningsmönster på grund av skadediagnoser (omedelbar, episodisk, senare och kombinerat med andra diagnoser). Två kluster hade sjukskrivning på grund av andra diagnoser (korta respektive långa perioder) och ett kluster bestod huvudsakligen av individer med sjuk- eller aktivitetsersättning. Jämfört med klustret ”Ingen sjukfrånvaro” var alla andra kluster förknippade med högre ålder, att bli inlagd på sjukhus i samband med olyckan och arbete inom vård och omsorg. Klustren "Omedelbar sjukskrivning", "Episodisk sjukskrivning" och "Både sjukskrivning

på grund av skadediagnos och andra diagnoser" hade högre OR för frakturer.
I **Studie V** var en tredjedel av de skadade cyklister, 31 % var bilister, 16 % var fotgängare och 19 % var skadade i andra olyckor (mestadels motorcykel och moped). Fotgängare och andra trafikanter var de grupper som hade högst medelantal av sjukskrivningsdagar under det första året efter olyckan (51 respektive 49 dagar/år). De matchade referenserna hade mellan 8 och 13 sjukskrivningsdagar/år under hela studieperioden (ett år innan till och med fyra år efter). Alla trafikantgrupper hade högre medelantaldagar/år än sina matchade referenser under hela studieperioden. Överskott av sjukskrivning på grund av skadediagnoser var 15–35 dagar/år under det första året efter olyckan. Överskott av sjukskrivning på grund av andra diagnoser än skador var för fotgängare och bilister cirka åtta dagar/år under hela studieperioden och cirka noll för cyklisterna. Överskott av sjuk- och aktivitetsersättning var låg, det ökade något varje år för fotgängare och bilister, men för cyklister observerades inget sådant överskott.

**Slutsatser:**
Denna avhandling visar att bland skadade cyklister och fotgängare hade cirka en femtedel ny sjukskrivning i samband med olyckan. Både cyklister och fotgängare hade överskott av sjukskrivning jämfört med deras matchade referenser. Däremot var det en lägre andel cyklister än fotgängare med pågående sjukfrånvaro vid tidpunkten för olyckan, dessutom minskade cyklisternas överskott av sjukfrånvaro efter olyckan snabbare än för fotgängarna jämfört med deras respektive referenser. Frakturer var förknippade med sjukskrivning i samband med olyckan för både cyklister och fotgängare, traumatisk hjärnskada var bland cyklisterna förknippade med långvarig sjukfrånvaro.

# List of scientific papers

I. Kjeldgård L, Ohlin M, Elrud R, Stigson H, Alexanderson K, Friberg E. Bicycle crashes and sickness absence - a population-based Swedish register study of all individuals of working ages. BMC Public Health 2019, 19(1):943*

II. Kjeldgård L, Stigson H, Alexanderson K, Friberg E. Sequence analyses of sickness absence and disability pension in the year before and the three years following a bicycle crash; a nationwide longitudinal cohort study of 6353 injured individuals. BMC Public Health 2020; 20:1710*

III. Kjeldgård L, Stigson H, Klingegård M, Alexanderson K, Friberg E. Sickness absence and disability pension among injured working-aged pedestrians - a population-based Swedish register study. BMC Public Health 2021; 21(1):2279

IV. Kjeldgård L, Stigson H, Bergsten EL, Farrants K, Friberg E: Diagnosis-specific sickness absence among injured working-aged pedestrians: a sequence analysis. BMC public health 2023; 23(1):367

V. Kjeldgård L, Stigson H, Farrants K, Friberg E: Sickness absence and disability pension after a road traffic accident, a nationwide register-based study comparing different road user groups with matched references. In manuscript.

*Paper was also included in the licentiate thesis: "Sickness absence and disability pension among individuals injured in a bicycle crash" 2020.

# Contents

# List of abbreviations

| | |
|---|---|
| AIS | Abbreviated Injury Scale |
| CDR | Cause of Death Register |
| CI | Confidence interval |
| DP | Disability pension |
| ICD-10 | International Classification of Diseases, version 10 |
| LISA | Longitudinal Integration Database for Insurance and Labour Market Studies |
| MiDAS | Micro Data for Analysis of the Social Insurance |
| NPR | National Patient Register |
| OR | Odds ratio |
| PMI | Permanent Medical Impairment |
| RPMI | Risk of Permanent Medical Impairment |
| SA | Sickness absence |
| SCB | Statstics Sweden |
| SDG | Sustainable Development Goals |
| STRADA | Swedish Traffic Accident Data Acquisition |
| $T_0$ | The accident date |
| TBI | Traumatic brain injury |
| UN | The United Nations |
| $W_0$ | Week zero, the week of three days before and three days after the accident date ($T_0$) |

# 1 Introduction

Road traffic injuries are globally among the leading causes of death and disability, and contribute to 1.3 million deaths per year. In addition, between 20 and 50 million individuals suffer non-fatal injuries which could lead to disability as a result of their injury. Road traffic injuries were the sixth leading cause of disability-adjusted life years in 2019. Sweden adopted "Vision Zero" in 1997, stating that no one should die or suffer injuries leading to long-term consequences within the road transport system. In 2010 the decade of action for road safety was proclaimed by the United Nations' (UN) General Assembly, and in 2015 the UN global sustainable development goals (SDG) were adopted. The SDGs strive for safer and more sustainable transportation in two of the goals: to reduce the number of death and injuries from road traffic accidents by half by 2020, and to provide access to safe, affordable, accessible and sustainable transport systems for all.

As the work with road safety has progressed, the number of fatal and serious injuries has decreased, but not at a sufficient pace to meet the goals. In Sweden, the number of severely injured individuals has decreased mostly among car occupants. However, the same decline has not been seen among bicyclists, who are now the road user group with the highest number of severe injuries. The number of severely injured pedestrians is low in the official statistics, as only those pedestrian accidents where a vehicle in motion is involved in the accident are included. The vast majority of pedestrian injuries within the road transport system are fall accidents, thus, fall injuries warrant attention when studying the consequences of road traffic injuries. Being injured in a road traffic accident may affect the individual's physical and mental health, both in the short and long term. As a result, the individuals' work ability could be affected and lead to sickness absence (SA) and disability pension (DP). Knowledge is lacking on the short- and long-term consequences of road traffic injuries among bicyclists and pedestrians in terms of SA and DP. Therefore, it is of relevance to study if and to what extent injured bicyclists and pedestrians have SA and DP after an accident and if their injuries impact SA or DP several years after the accident.

This thesis expands and deepens the knowledge of SA and DP among pedestrians and bicyclists in working ages who were injured in a road traffic accident in Sweden.

# 2 Background

This thesis investigates sickness absence (SA) and disability pension (DP) among bicyclists and pedestrians injured in road traffic accident (including fall accidents). First, some background on bicycling and walking as a sustainable transportation is presented, second, road traffic accidents and the classification of injuries sustained in such accidents are presented, third, considerations regarding SA and DP are presented, and finally, consequences of road traffic injuries in terms of SA and DP are presented.

## 2.1 Sustainable transportation

Active transportation such as walking and bicycling provides an opportunity for individuals to incorporate physical activity into their daily life. Physical activity has a positive impact on public health and increased walking and bicycling is an important aspect of a sustainable road transport system[1-3]. Therefore, active transport is encouraged by different stakeholders[3-7]. Two important reasons for this are that increased bicycling and walking is an essential complement to reduce vehicle congestion and greenhouse gas emissions[1] and a way of increasing physical activity in the population. The positive effects of physical activity on health are well-known and physical inactivity is recognized as a major public health problem[8]. Several recent studies have highlighted the positive health effects of increased bicycling[9-13], both for the individuals themselves due to increased physical activity, and to the general population due to less exposure to air pollution[10, 12, 13].

The United Nations' (UN) global sustainable development goals (SDG) strive both for more sustainable and safer transportation[3, 6]. Two of the targets of the UN 2030 Agenda for sustainable development include road safety and the latter also highlights sustainable transportation[3], namely;

- 3.6: By 2020, halve the number of global deaths and injuries from road traffic accidents
- 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

The recognition of these targets places road safety at the same level as the UN's other sustainability goals, which indicates that sustainable health and well-being cannot be achieved without reducing deaths and severe injuries from road traffic[14].

## 2.2 Road traffic accidents

Globally, road traffic injuries contribute to 1.3 million deaths per year[6]. In addition, between 20 and 50 million individuals suffer non-fatal injuries which could lead to disability as a result of their injury[6]. The European Commission estimates that for every person killed in traffic accidents, another five suffer serious road traffic injuries[15]. Road traffic injuries were, as a group, the sixth leading cause of disability-adjusted life years in 2019[6, 16].

In 2010, a decade of action for road safety was proclaimed by the UN General Assembly[17]. Furthermore, road safety was included in two of the targets of the UN 2030 Agenda for sustainable development in 2015[3]. However, at the 3$^{rd}$ Global Ministerial Conference on Road Safety, held in Stockholm in the beginning of 2020, it was recognized that target "3.6", to reduce the number of global deaths and injuries from road traffic accidents by half to 2020, had not been met[14]. The outcome of this conference was the Stockholm Declaration, calling upon member states to continue reducing road deaths by at least 50% from 2020 to 2030 and to continue the action on road safety related sustainable development targets, including “3.6” also after 2020[18]. Globally, a majority of the road traffic injuries are non-fatal but could lead to long-term consequences. Hence, it is essential to also focus on non-fatal outcomes[19].

As the work with road safety has progressed, e.g., with Vision Zero that was adopted in Sweden 1997 with the long-term goal that no one should die or suffer injuries leading to long-term consequences within the road transport system[20-23], the number of fatal and serious injuries have decreased[24].

Traditionally, information on road accident casualties is based mainly on police-reported death and severe injuries[25]. However, this may not adequately describe the situation since there is an under-reporting of the number of accidents in the police data, especially among pedestrians and bicyclists[26]. In Sweden, only 7% of all bicycle crashes are covered in the police reports[27], possibly because most of the crashes are single-bicycle crashes. In Sweden the national system for road traffic injury collection “Swedish Traffic Accident Data Acquisition” (STRADA)[28] contains police-reported road traffic accidents and data on individuals who received medical treatment at the emergency department in Swedish hospitals. Another important source for information on road traffic injuries are healthcare register data, including both emergency and non-emergency visits/hospitalizations, that cover a larger proportion of bicycle and pedestrian accidents[29], especially in Sweden where the validity of the Swedish National Inpatient Register is high[30, 31]. Furthermore, Sweden has a universal public healthcare insurance, with low out of pocket costs for healthcare[32].

### 2.2.1 Bicycle injuries

The number of serious injuries has decreased especially among car occupants[33]. Still, efforts have not been as successful for bicyclists, which has led to more focus on bicyclists[7, 34, 35]. Bicyclists are the road user group with the highest number of severe injuries in the European Union, and in Sweden[24, 36]. Previous research has shown that a 29-times higher risk for injury and 10-times higher risk of fatality has been observed among bicyclists compared to car occupants[37]. The most common type of crash among bicyclists is single-bicycle crashes[1, 27, 38-41], and the most frequent types of injury are fractures and external injuries[15, 42], while the most commonly injured body regions are upper extremities and head[39-44].

### 2.2.2 Pedestrian injuries

Globally, pedestrians represent about a fifth of all fatalities within the road transport system[6, 45]. In the European Union, pedestrians represent the road user group with the highest proportion of accidents resulting in hospital admission[46]. Nevertheless, the current definition of traffic injuries[47] only includes pedestrians struck by vehicles. Several studies have indicated that if pedestrians’ falls in road environments were included, the number of injuries in this group would be much higher[7, 41]. Thus, in order to avoid underestimation of injuries among pedestrians, accidents from falls sustained in the road transport system should be taken into consideration.

In Sweden, targets for pedestrian falls have been added to the national road safety targets for 2030, which are to halve the number of fatalities and reduce the injuries with long-term consequences by 25%[48]. The target for fall injuries has been set by the Swedish Transport Administration within a national group of stakeholders in the road transport area[49-51].

The most frequently reported types of injuries among pedestrians are fractures and external injuries, and the injured body regions most frequently reported are lower and upper extremities[4, 15, 42].

### 2.2.3 Classification of road traffic injuries

A classification of injuries according to severity is necessary to be able to quantify the targets for road traffic safety. The severity and seriousness of an accident can be classified in several ways. The Abbreviated Injury Scale (AIS), published by the Association for the Advancement of Automotive Medicine, is used internationally to describe the severity of an injury, on a scale from 1 to 6, for nine body regions: 1 Head, 2 Face, 3 Neck, 4 Thorax, 5 Abdomen, 6 Spine, 7 Upper Extremity, 8 Lower Extremity, 9 External and other. The severity goes from 1 Minor up to 6 Unsurvivable[29, 52]. AIS is coded for each injury, in order to reflect the combined effects of multiple injuries the Maximum Abbreviated Injury Scale (MAIS) is often used to highlight the maximum AIS score for the individual. The European Union uses MAIS 3+ (any injury of AIS 3 or higher) as a definition of serious injury[53]. Another index is the Injury Severity Score (ISS) that provides an overall score of the individuals' injuries by adding the squared AIS of the three body regions with highest AIS score. In Sweden, Vision Zero with the goal that no one should die or suffer injuries leading to long-term consequences within the road transport system, uses risk of Permanent Medical Impairment (RPMI) as target measure, as RPMI also captures the long-term consequences of the road traffic accident. This definition is based on insurance data to classify if an injured road user still had residual symptoms three years after a crash. The RPMI is an estimation of the risk of suffering permanent medical impairment (PMI) from an injury classified according to AIS[54]. Another scale that is often used is to measure how a road traffic accident affects an individual's perception of quality of life[55, 56]. Sustaining a PMI has negative effects on the individual's health related quality of life and lowers the individual's physical activity after the accident[57]. In addition, an injury could affect the individual's work capacity and lead to sickness absence (SA) and disability pension (DP). A previous study has shown an association between DP and PMI, especially for higher PMI grades[58].

### 2.2.4 Factors associated with road traffic accidents

The risk of being involved in road traffic accident, the risk of being injured in the accident, and the severity outcome of the injuries are influenced by various factors (e.g., mode of transportation, numbers of trips, distance travelled, and road environment). In one sense we are all pedestrians during parts of or during the whole journey, regardless of other transportation taken. However, only those who cycle can be involved in a bicycle crash. Travel habits vary, and with that, the risk of being involved in an accident. According to the Swedish travel survey, women and men take equal numbers of bicycle trips, but men generally bicycle longer distances than women. In contrast, women walk more often and walk longer distances than men[38]. Not only the type of transportation mode and the use of it, but also the risk of being involved in an accident and the risk of sustaining an injury if involved in an accident could vary. For example, older individuals are overrepresented among pedestrians[4, 59] and more likely to get a fracture when falling[60]. Moreover, the road environment affects the risk of being involved in an accident. For example, snow and ice are associated with a higher risk of falling[59, 61, 62]. In addition, different injuries have different severity levels[54, 63]. The proportions of the different injured body region vary for different severity levels of the injury (e.g., among bicyclists, injuries to the shoulders and arms account for about a fifth of all injuries, but when only counting the severe injuries, the proportion of injuries to the shoulders and arms increase to about half of the injuries)[38].

## 2.3 Sickness absence and disability pension

Being injured in a road traffic accident may affect physical as well as mental health[64], which could negatively affect individuals' work ability and lead to SA and DP. Sickness absence and DP does not only impact the individual but the family, colleagues, employers, insurers, healthcare, and the society as a whole[65-67].

### 2.3.1 The Swedish public sickness absence insurance system

All individuals living in Sweden, ≥16 years old, and with income from work, unemployment, or parental-leave benefits can get SA benefits if they have a disease or injury leading to reduced work capacity[68]. Sickness absence benefit covers temporary work incapacity due to morbidity. During the years studied in this thesis, the first day of a SA spell was an unreimbursed qualifying day (varying number of days for self-employed). A physician's certificate was required from the eighth day. For most employees, day 2-14 are reimbursed by the employer, thereafter, by the Social Insurance Agency. For others, e.g., unemployed, the Social Insurance Agency administrates benefits from the second day of SA. All individuals aged 19-64 can be granted DP if their disease or injury leads to long-term or permanent work incapacity. The public benefits for SA cover 80% of lost income up to a certain level, and for DP 64% of lost income up to a certain level. Both SA and DP can be granted for full- or part-time (100, 75, 50, 25%) of ordinary work hours. That is, someone on part-time DP can have part-time SA at the same time. The extent of the spells can vary over time, (e.g., an individual could first be on 50% SA, then 100% SA, and then go back to 50% SA). Part-time SA at the end of a SA-spell could be beneficial for reintegration into the labour market[69]. Part-time SA and DP could also be beneficial e.g., for lowering the individuals' risk of social isolation, which could be a negative side-effect of SA and DP[67].

### 2.3.2 Measures of sickness absence and disability pension

Sickness absence and DP can be measured in many different ways, and there are several aspects to consider when measuring them. For example, which type of spells (e.g., new, ongoing, or concluded), durations of spells, recurrent spells, the extent of the spells (e.g., full- or part-time), and diagnoses of the spells. In Sweden as in other countries, the distribution of the duration of SA spells is usually very skewed as most of the SA spells are short-term spells[70, 71]. Even though only 2% of all SA spells in Sweden are longer than 90 days, those spells contribute to about half of all SA days[70, 71]. In addition, as both SA and DP can be granted for part-time, at least in the Nordic countries, some individuals have both SA and DP at the same time. Moreover, for some individuals SA may transition into DP. In addition, timeframe (e.g., a single timepoint, calendar days, working days, compensated days, and absent days) and which individuals to take into consideration (e.g., number exposed, insured, in paid work, and individuals with SA) needs to be decided upon. All these aspects have led to that there are more than one hundred different measures of SA and DP in the literature[72-74], as they can be used and combined in several different ways[72, 73] (e.g., number of net days/year and duration of new SA spells). All these measures reveal the complexity of measuring SA and DP, and the choice of measure can be crucial as different measures can lead to different results (e.g., there are for example sex-differences in the number SA days per person in paid work, but not per person with SA)[75].

The risks of SA and DP and other such events have mainly been analysed with different types of traditional regression analyses in previous studies[76, 77]. That is, the focus has been on the outcome at a single point in time, either in a cross-sectional study, or time to first event, or at the end of follow-up in a longitudinal study.

For studying SA and DP over time, several aspects need to be taken into consideration, not only at the end of follow-up, but also the sequence/patterns of SA and DP during the whole follow-up time, e.g., individuals' timing, duration, and order of different types of events. Sequence analysis could be a suitable method for this, and interest for such analyses has increased[78-81]. Several studies that used sequence analysis showed that the heterogeneity in the sequences can add additional value and be a good complement to traditional regression analysis[79, 80, 82]. Thus, more comprehensive methods, such as sequence analysis, could be used in order to broaden the knowledge of SA and DP in relation to road traffic accidents in a long-term perspective.

### 2.3.3 Factors associated with sickness absence and disability pension

Several previous studies have shown associations between different sociodemographic factors and SA[66, 76, 83-86]. A systematic review summarized that women, individuals in older age groups, and individuals with lower socio-economic status have a higher probability for SA[83]. Generally, higher education is associated with lower levels of SA[87]. Having a higher level of education, could imply more opportunities to change to different occupations or to other work tasks if needed to be able to work despite some limitations/work incapacity related to the previous work tasks. Different work tasks and occupations place different demands on the worker. Hence, individuals work tasks and occupation influence SA and DP as those are granted if the individuals have a disease or injury leading to reduced work capacity[75, 88]. In addition, country of birth, type of living area, and marital status have been shown to be associated with SA and DP[89, 90]. Furthermore, previous SA and DP have been reported to be associated with future SA[86, 91, 92] as well as with future DP[89, 90].

## 2.4 Sickness absence and disability pension after a road traffic accident

Sickness absence has been shown to be relatively common after a road traffic injury[39, 40, 93-96]. Among car occupants 9% had new SA in connection with a road traffic accident[94]. Older age and being female are risk factors for SA and DP both in general[83] and after a road traffic injury[93, 94, 96-98]. Long-term consequences in terms of SA and DP for car occupants has been studied, showing increased number of SA and DP days in the four years following the accident[99]. In addition, having ongoing SA and DP at the time of the crash have shown to be associated with SA and DP two years after a car crash[58]. Furthermore, comorbidity has been showed to be a risk factor for future SA and DP generally[83] as well as a risk factor for being involved in a road traffic accident[100]. These studies focused on all type of road users' or in particular car occupants' accidents: SA and DP have been less studied among bicyclists and pedestrians.

### 2.4.1 Sickness absence and disability pension among injured bicyclists

Few studies have been published regarding SA and DP after a bicycle crash[39, 40, 43, 95, 98, 101, 102]. Three of these studies are more than 20 years old and were based on relatively small samples of individuals who received medical treatment at Swedish and Finnish emergency departments in specific hospitals (425-542 individuals)[39, 40, 95]. Furthermore, these studies did not consider DP or ongoing SA at the time of the crash, that is, individuals not at risk of a new SA spell at the time of the crash. A more recent study investigated the duration of SA following a bicycle crash, among all bicycle crashes registered in inpatient and specialized outpatient healthcare in Sweden[43]. This study found that 20% had SA >14 days after a bicycle crash and that the duration of SA varied with the injured body region and type of injury. It also showed that the duration of SA following a bicycle crash was associated with several sociodemographic factors (sex, age, level of education, and country of birth)[43]. A Finnish study on bicycle crashes and SA showed an age-related trend, where the mean duration of self-reported work disability increased with age[39].

A study from Australia on work absence (compensated days off work) following a road traffic accident found a lower risk for prolonged work absence among bicyclists and motorcyclists compared to car occupants[98]. A study from France on 581 individuals (of which 62 were bicyclists) injured in a road traffic accident, found that a slightly higher proportion among late return to work were motorcyclists and a slightly higher proportion among earlier return to work were bicyclists, however, these differences were not significant[101].

### 2.4.2 Sickness absence and disability pension among injured pedestrians

Little is known about the consequences of road traffic injuries among working-aged pedestrians in terms of SA and DP[95, 101, 102], especially among fall injuries, since they are not included in official statistics and police reports[7, 26, 47]. One study from Australia found that 60% of pedestrians hospitalized for an orthopedic injury following a road traffic accident (fall injuries not included) had returned to work after 6 months and 63% after 12 months[102]. That study found higher odds for returning to work among the bicyclists compared to pedestrians[102]. However, the study from France on 581 individuals (of which 57 were pedestrians) injured in a road traffic accident did not find any significant differences in return to work between road user groups[101].

To summarize, the knowledge of SA and DP, both in direct connection with the accident and the long-term perspective, among injured pedestrians and bicyclists is highly limited.

# 3 Research aims

The overall aim of this thesis was to generate broader and deeper knowledge of SA and DP after a road traffic accident among injured working aged bicyclists and pedestrians.

## 3.1 Specific aims

*Study I:* The aim of Study I was to explore SA and DP among individuals of working ages who were injured in a bicycle crash, both in general and by different sociodemographic factors, crash type, type of injury, and injured body region.

*Study II:* The aim of Study II was to identify long-term patterns of SA and DP among injured bicyclists and to explore factors associated with those specific patterns regarding crash and injury characteristics by adjusting for sociodemographic characteristics.

*Study III:* The aim of Study III was to explore SA and DP among individuals of working ages who were injured as a pedestrian, both in general and by different sociodemographic factors, type of accident, type of injury and injured body region.

*Study IV:* The aim of Study IV was to identify long-term diagnosis-specific patterns of SA and their association with different sociodemographic, occupational and injury-related factors among individuals of working ages who were injured as a pedestrian.

*Study V:* The aim of Study V was to estimate excess diagnosis-specific SA and DP among individuals injured in a road traffic accident, for different road user groups, compared to matched references without such injury.

# 4 Materials and methods

Five register-based studies were conducted; the design, data, outcome, and analyses of these studies are summarized in Table 1.

**Table 1.** Overview of the five studies

| | Study I | Study II | Study III | Study IV | Study V |
|---|---|---|---|---|---|
| **Aim** | To explore SA and DP among individuals of working ages who were injured in a bicycle crash, both in general and by different sociodemographic factors, crash type, type of injury, and injured body region | To identify long-term patterns of SA and DP among injured bicyclists and to find characteristics associated with the specific patterns | To explore SA and DP among individuals of working ages who were injured as a pedestrian, both in general and by different sociodemographic factors, type of accident, type of injury and injured body region | To identify long-term diagnosis-specific patterns of SA and their association with different sociodemographic, occupational and injury-related factors among individuals of working ages who were injured as a pedestrian | The aim of Study V was to estimate excess diagnosis-specific SA and DP among individuals injured in a road traffic accident, for different road user groups, compared to matched references without such injury. |
| **Design** | Register based cross-sectional population-based study | Register-based longitudinal population-based cohort study with prospective and retrospective weekly measurements, for four years (one year before and three years following a bicycle crash) | Register based cross-sectional population-based study | Register-based longitudinal population-based cohort study with prospective and retrospective weekly measurements, for four years (one year before and three years following a pedestrian accident) | Register-based longitudinal population-based cohort study with matched references from general population. Prospective and retrospective yearly measurements, during five years (one year before and four years following a road traffic accident) |
| **Data sources** | LISA, NPR, CDR, MiDAS | LISA, NPR, CDR, MiDAS | LISA, NPR, CDR, MiDAS | LISA, NPR, CDR, MiDAS | LISA, NPR, CDR, MiDAS |
| **Study population; N** | 7643 (16-64 years; 43.2% women) | 6353 (18-59 years; 43.0% women) | 5576 (16-64 years; 56.2% women) | 11,432 (20-59 years; 54.3% women) | 121,062 (20-59 years; 40.4% women) |
| **Inclusion criteria** | On 31 December 2009: living in Sweden, aged 16-64 years and receiving in- or specialized outpatient healthcare in 2010 due to injuries sustained in a bicycle crash | Same as in study I but limited to 18-59 years | On 31 December 2009: living in Sweden, aged 16-64 years and receiving in- or specialized outpatient healthcare in 2010 due to injuries sustained in a pedestrian accident (including falls) | Receiving in-or specialized outpatient healthcare 2014-2016 due to injuries sustained in a pedestrian accident (including falls). On 31 December the year before the accident: living in Sweden, aged 20-59 years | On 31 December 2014: living in Sweden 20-59 years and receiving in- or specialized outpatient healthcare in 2015 due to injuries sustained in a road traffic accident. Five matched refences to each injured individual |
| **Exclusion criteria** | Transport-related injuries during three years prior to the inclusion date | Same as in Study I, and died or emigrated during the three years after the inclusion date | Transport-related injuries (including falls) during three years prior to the inclusion date | Transport-related injuries (including falls) during two years prior to the inclusion date, died or emigrated during follow-up, DP during the whole study-period | Transport-related injuries (including falls) during 2014, died or emigrated 2015-2019, not in paid work 2014 |

| | | | | | |
|---|---|---|---|---|---|
| **Outcome measures** | No SA or DP, New SA, and Ongoing SA or full-time DP | Clusters of sequences of weekly states on SA and DP during 4 years | No SA or DP, New SA, Ongoing SA, and Full-time DP | Clusters of sequences of weekly states on SA and DP during 4 years | Mean annual net days of SA and DP. Excess SA and DP net days/year |
| **Factors included in the analyses** | Sex, age, level of education, country of birth, type of living area, marital status, type of crash, specialized healthcare, type of injury, injured body region | Sex, age, level of education, country of birth, type of living area, marital status, type of crash, specialized healthcare, type of injury, injured body region | Sex, age, level of education, country of birth, type of living area, marital status, part-time DP, type of accident, specialized healthcare, type of injury, injured body region | Sex, age, level of education, country of birth, type of living area, marital status, type of accident, specialized healthcare, type of injury, injured body region, season, year of accident, occupational sector, private/public, type of occupation | Sex, age, level of education, country of birth, living in cities, marital status, mental comorbidity, musculoskeletal comorbidity, other comorbidities, specialized healthcare, type of injury, injured body region |
| **Statistical analyses** | Descriptive statistics, logistic regression | Descriptive statistics, sequence analysis, cluster analysis, multinomial logistic regression | Descriptive statistics, logistic regression | Descriptive statistics, sequence analysis, cluster analysis, multinomial logistic regression | Descriptive statistics, t-tests with bootstrapped confidence interval |

Abbreviations: SA: Sickness absence; DP: Disability pension; LISA: Longitudinal Integration Database for Insurance and Labour Market Studies; NPR: National Patient Register; CDR: Cause of Death Register; MiDAS: Micro Data for Analysis of the Social insurance.

## 4.1 Design and study populations

Study I, II, and III have the same study base, all 5 982 221 individuals 16-64 years of age, living in Sweden 31 December 2009. Study I included all individuals 16-64 years who in 2010 received in- or specialized outpatient healthcare due to an injury from a new bicycle crash. Study II was restricted to those aged 18-59 years; as the cohort was studied one year before through three years after the bicycle crash, they all needed to be at risk for the outcomes SA and DP during the full study period. Further, in order to have complete follow-up data for all included, those who died or emigrated during the three years following the crash were excluded. Study III included all pedestrians aged 16-64 years, who in 2010 received in- or specialized outpatient healthcare due to an injury sustained in a new traffic-related accident, including falls.

Study IV included all pedestrians who in 2014-2016 received in- or specialized outpatient healthcare due to an injury sustained in a new traffic-related accident including falls, aged 20–59 years and living in Sweden 31 December the year before the accident. Those who died or emigrated during the three years following the accident were excluded as well as those with DP during all the 209 weeks of the four-year study period.

Study V included all individuals 20-59 years old and living in Sweden 31 December 2014 who during 2015 received in- or specialized outpatient healthcare due to an injury sustained in a new traffic-related accident. Those who died or did not live in Sweden during 2015-2019 were excluded. Furthermore, those not in paid work during 2014 were excluded. Each individual was matched (exact matching without replacement) to five references without any road traffic accident during 2014 and 2015, living in Sweden 2014-2019, and in paid work during 2014.

In Figure 1 an illustration of the included bicyclists and pedestrians can be seen. Information on whether someone bicycles or walks is not available from the register data, nor whether they are involved in an accident or injured in the accident (especially minor injuries, where the individuals do not need healthcare or only need primary healthcare). It is important to keep in mind that only those seeking secondary (i.e., in- or specialized outpatient) healthcare after an injury sustained in an accident are included in the thesis.

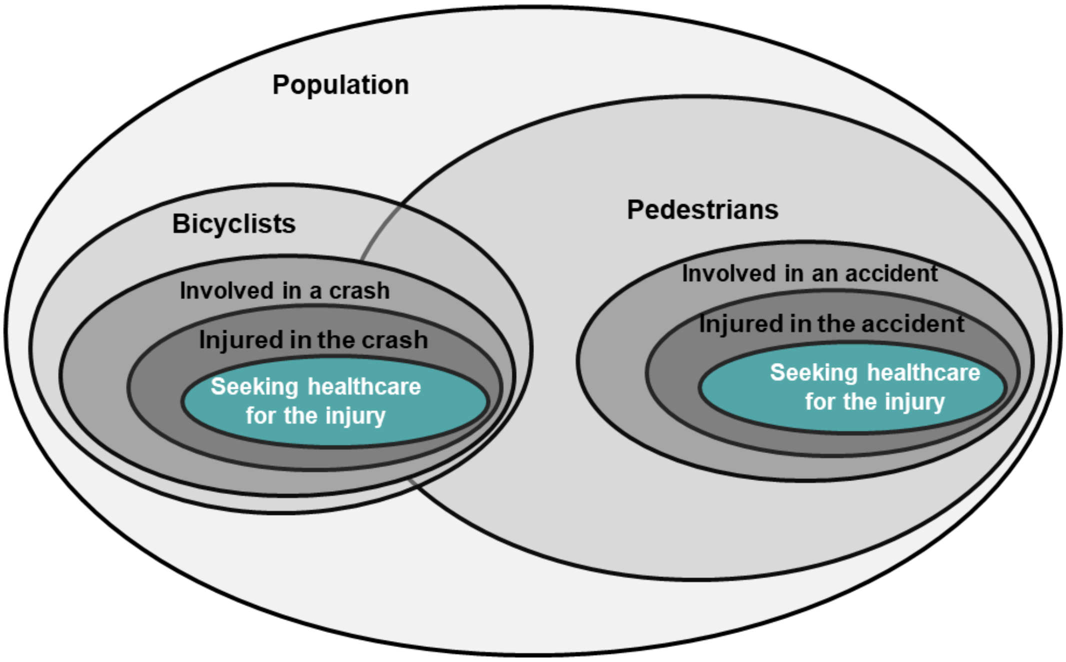


**Figure 1**. Illustration of study population for the included bicyclists and pedestrians (not drawn to proportion).

## 4.2 Data sources

All five studies in this thesis were based on pseudonymized microdata from Swedish nationwide registers administrated by Swedish authorities and linked at the individual level using the personal identity number assigned to all individuals resident in Sweden[103]. More details on the used registers and which data that were used in the thesis are presented below.

### 4.2.1 Longitudinal Integration Database for Insurance and Labor Market Studies (LISA)

The Longitudinal Integration Database for Insurance and Labour Market Studies (LISA) (Swedish: Longitudinell integrationsdatabas för Sjukförsäkrings- och arbetsmarknadsstudier) is maintained by Statistics Sweden (SCB) and contains annual information on sociodemographic and social insurance benefits for all individuals 16 years or older living in Sweden 31 December of each year[104, 105].

LISA data was used to identify all individuals (Study I and Study III: aged 16-64, Study II: aged 18-59, Study IV and Study V: aged 20-59) living in Sweden 31 December the year before their index accident and to identify those still living in Sweden during follow-up (Study II, IV and V). LISA data was used to obtain information regarding sociodemographic factors; sex, age, level of education, type of living area, and marital status, as well as work-related factors; occupational sector, private/public, type of occupation, and income from work at baseline.

### 4.2.2 The National Patient Registers (NPR)

The two National Patient Registers (NPR) (Swedish: Patientregistret) are kept by the National Board of Health and Welfare and include information regarding inpatient and specialized outpatient healthcare. They do not include information from primary healthcare. The registers have good coverage regarding the information needed for the studies in this thesis; for inpatient healthcare 99% of the hospitalizations have a diagnosis and 98% of those with injuries have a stated cause; the corresponding numbers for specialized outpatient healthcare are 98% and 83%, respectively[106].

Information on all hospitalizations and all physician visits to specialized outpatient healthcare regarding dates, main diagnosis, secondary diagnoses, and external causes was obtained from the NPR.

The external causes were used to identify all individuals included in the studies. ICD10-codes[107, 108] used for inclusion and exclusion are presented in Table 2.

**Table 2.** Overview of ICD10-codes used for inclusion and exclusion in the five studies

| | Study I | Study II | Study III | Study IV | Study V | |
|---|---|---|---|---|---|---|
| | | | | | Injured | References |
| **Inclusion period** | 2010 | 2010 | 2010 | 2014-2016 | 2015 | |
| **Included ICD10-codes** | V10-V19 | V10-V19 | V01-V09, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 | V01-V09, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 | V01-V79, V80.2-V80.5, V82, V83.0-V83.3, V84.0-V84.3, V85.0-V85.3, V86.0-V86.3, V87, V89.2, V89.3, V89.9, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 | |
| **Wash-out period** | Three years prior crash | Three years prior crash | Three years prior accident | Two years prior accident | 2014 | 2014-2015 |
| **Excluded ICD10-codes** | V01-V99 | V01-V99 | V01-V99, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 | V01-V99, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 | V01-V79, V80.2-V80.5, V82, V83.0-V83.3, V84.0-V84.3, V85.0-V85.3, V86.0-V86.3, V87, V89.2, V89.3, V89.9, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 | V01-V79, V80.2-V80.5, V82, V83.0-V83.3, V84.0-V84.3, V85.0-V85.3, V86.0-V86.3, V87, V89.2, V89.3, V89.9, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4 |

In Study I and Study II individuals who received inpatient and specialized outpatient healthcare due to bicycle crashes were included. In Study III and Study IV individuals who received inpatient and specialized outpatient healthcare due to pedestrian accidents (including falls and bumping into other pedestrians) were included. In Study V individuals who received inpatient or specialized outpatient healthcare due to road traffic accidents (including pedestrian falls as in Study III and Study IV) were included. Further, to ensure that only the individuals who had actually been injured were included, all five studies only included the individuals if the main or secondary diagnoses were due to injury diagnoses (ICD10: S00-T89 “Injury, poisoning and certain other consequences of external causes”).

They also had to be able to be classified according to the Barell-classification[109]. In Study I and Study II also those with ICD10: Z04.1 “Examination and observation following transport accident” were included.

The date of the first such visit/hospitalization during the year(s) of inclusion for each individual was used as a proxy for the accident date, denoted as $T_0$, and will hereafter be referred to as the accident date or $T_0$, as the actual date of the accident is not included in NPR. For the matched references in Study V, $T_0$ refers to the date of $T_0$ for the injured individual. Further, to ensure that the included injuries were incident, i.e., that the registered healthcare was not due to repeat visits/hospitalizations following a previous accident, individuals with transport accident prior to their accident date ($T_0$) were excluded (a so-called wash-out period). See Table 2 for ICD10-codes and wash-out periods for the respective studies.

The inpatient and specialized outpatient healthcare was also used to obtain information on comorbidity in Study V.

#### 4.2.3 Micro Data for Analysis of the Social Insurance (MiDAS)

The register Micro Data for Analysis of the Social insurance (MiDAS) (Swedish: MikroData för Analys av Socialförsäkringen) is administrated by the Swedish Social Insurance Agency and includes detailed information on all spells of SA and DP with benefits paid by the Agency.

Information on SA and DP (start and end dates, diagnoses, and extent (full- or part-time)) was obtained for Study I and Study III in relation to the date of the accident ($T_0$), for Study II and Study IV during one year (365 days) before through three years after the accident date ($T_0$), and for Study V during one year before and four years after the accident date ($T_0$).

#### 4.2.4 The Cause of Death Register (CDR)

The Cause of Death Register (CDR) (Swedish: Dödsorsaksregistret) is administered by the National Board of Health and Welfare and contains information on date and causes of death among all Swedish residents[110].

Information on date of death was obtained from this register and was used in Study I and Study III to identify those who died within 30 days after the accident and in Study II, Study IV, and Study V to exclude those who died during the follow-up period.

### 4.3 Exposure, covariates, and outcome measures

Information on the exposure, covariates and outcome measures used in the five studies is described below. All sociodemographic and work-related factors were obtained for 31 of December of the year before $T_0$, and all accident- and injury related factors were obtained at $T_0$. Comorbidity was obtained during one year before $T_0$. The outcome SA and DP were measured during different time frames for the different studies, described in more detail below.

#### 4.3.1 Accident-related factors

The categorizations of the road traffic accidents are described in more detail below. The term accident is used for pedestrians and road traffic accidents among all road user groups, while the term crash is used for bicyclists. Accident is also used when discussing accidents in general or among both pedestrians and cyclists (e.g., time of the accident, $T_0$). All visits to specialized outpatient healthcare and hospitalizations in inpatient healthcare have a main diagnosis/injury and could also have one or several secondary diagnoses/injuries (ICD-10 codes). The visits/hospitalizations also have ICD-10 codes for external causes of morbidity. The external causes of morbidity were used for categorization of type of accident, while the main and secondary diagnoses were used for categorization of the sustained injuries: type of injury and injured body region.

#### *4.3.1.1 Bicycle crashes*

Bicycle crashes was used as exposure in study I and II, and was categorized into three groups using the ICD-10 code for external causes of morbidity: single-bicycle crash (ICD10: V17, V18, V19.3, V19.8, V19.9), collision with pedestrian, animal, or other bicycle (V10, V11), and collision with motor vehicle (V12-V16, V19, V19.1, V19.2, V19.4-V19.6). Single-bicycle crash includes crashes such as bicycle rider injured in a collision with fixed or stationary object, and non-collision transport crashes (fall or thrown from bicycle). Further, bicycle riders injured in an unspecified crash were categorized as single-bicycle crashes.

#### *4.3.1.2 Pedestrian accidents*

Pedestrian accidents was used as exposure in study III and IV, and was categorized into the following six groups: collision with pedestrian/bicyclist (V01, W03.4, W04.4, W51.4), collision with motor vehicle (V02-V06, V09.0, V09.2); unspecified (V09.1, V09.3, V09.9, W19.4), fall - snow and ice (W00.4), fall - slipping, tripping, and stumbling (W01.4), and fall - other (W02.4, W05.4, W10.4, W15.4, W17.4, W18.4). Fall - other included accidents involving ice-skates, skis, roller-skates, skateboards, wheelchairs, falls on and from stairs and steps, from cliffs, from one level to another, and on the same level. ICD10-codes from chapter W ending with .4 indicate that the location of the accident was a street, highway or pathway. Hence, all the injuries included are in traffic environment, even though some of them are unspecified how the accident occured.

#### *4.3.1.3 Road user groups*

Road traffic accidents was used as exposure in Study V, and was categorized into four road user groups: pedestrians (V01-V09, W00.4, W01.4, W02.4, W03.4, W04.4, W05.4, W10.4, W15.4, W17.4, W18.4, W19.4, W51.4); bicyclists (V10-V19); car occupants (V40-V49); and other road users (V20-V39, V50-V79, V80.2-V80.5, V82, V83.0-V83.3, V84.0-V84.3, V85.0-V85.3, V86.0-V86.3, V87, V89.2, V89.3, V89.9). Other road users included motorcyclists, mopeds, truck drivers, bus occupants, 3-wheelers, equestrians, trams, and other vehicles.

#### *4.3.1.4 Season*

Season was used as a covariate in Study IV. The time of the year of the accident was categorized into seasons: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November).

### 4.3.2 Injury-related factors

The factors related to the injury, are based on the in- and specialized outpatient healthcare registers and presented below.

#### *4.3.2.1 Type of Injury and injured body region*

Type of injury and injured body region were used as exposure in the studies. Information on type of injury and injured body region was, as mentioned above, obtained for each visit/hospitalization in the inpatient and specialized outpatient healthcare register at $T_0$. Each visit/hospitalization had a main diagnosis and could also have several secondary diagnoses. Moreover, some individuals had up to six visits/hospitalizations registered in the patient registers at $T_0$. However, the majority had only one injury diagnosis. For the individuals with several injury diagnoses, one injury diagnosis was selected in the following hierarchy: the main injury diagnosis was selected over secondary diagnoses, diagnoses for in-patient healthcare were selected over diagnoses for specialized outpatient healthcare, and injury diagnoses over other types of diagnoses (ICD10: S00-S99 over T00-T88 and for Study I and Study II: T00-T88 over Z04.1).

A modified version of the Barell matrix[109] was then used to categorize the diagnoses into:
a) *type of injury*:
Fracture; dislocation; sprains and strains; internal (brain, spinal cord, and other internal organs); external (open wounds, contusions, and superficial injuries); and other and unspecified
b) *injured body region*:
Head, face and neck; vertebral column and spinal cord; torso; upper extremities; lower extremities; and other and unspecified.

The category head, face and neck was in Study I, Study II and Study V divided into the three categories: head, face and neck, not traumatic brain injury (TBI); TBI, not concussion; and concussion. The category TBI, not concussion includes all TBI except concussion (S06.0) and will hereafter be denoted as TBI.

In Study III and Study V the category upper extremities was divided into the three categories: shoulder and upper arm; forearm and elbow; and wrist, hand, and other arm. In the same two studies lower extremities was divided into the three categories: hip, upper leg, and thigh; knee; and lower leg, ankle, foot, and other leg.

#### *4.3.2.2 Healthcare*

Type of healthcare were used as exposure in the studies. In Study I, Study III, and Study V, healthcare at $T_0$ was categorized into three groups. First, those with only specialized outpatient healthcare, secondly, those with in-patient healthcare divided by the median duration of the hospital stay among those hospitalized in the respective study (Study I: ≤1 day, >1 day; Study III: <3 days, ≥3 days; Study V: ≤ 2 days; >2 days). If someone had both specialized outpatient healthcare and inpatient healthcare at $T_0$ they were categorized as having inpatient healthcare. For individuals with several hospitalizations at $T_0$ the one with longest duration was used.

In Study II and Study IV, the healthcare variable was named inpatient healthcare and dichotomized into: no (only visits to specialized outpatient healthcare at $T_0$), and yes (inpatient healthcare at $T_0$, may also have visits to specialized outpatient healthcare the same day).

### 4.3.3 Sociodemographic factors

The sociodemographic factors were used as covariates in the studies. All sociodemographic factors; sex, age, country of birth, level of education, type of living area, and marital status were obtained 31 December the year before $T_0$ from LISA.

In Study I and Study III age was categorized into five groups: 16-24 years, 25-34 years, 35-44 years, 45-54 years, and 55-64 years old and in Study II into two groups: 18-40 years, and 41-59 years old. In Study IV it was categorized into five groups: 20-24 years, 25-34 years, 35-44 years, 45-54 years, and 55-59 years old, and in Study V into two groups: 20-39 years and 40-59 years old.

Country of birth was categorized as Sweden, and not Sweden.

Level of education was in Study I-IV categorized into three groups: elementary (≤9 years), high school (10-12 years), and university/college (>12 years). In Study V elementary and high school were collapsed into one group, giving level of education two groups: elementary/high school and university/college.

Type of living area was in Study I, Study II, and Study III determined by population size of the municipality the individual lived in and categorized into the follow three groups: big cities (Stockholm, Göteborg, Malmö), medium-sized cities (with more than 90 000 inhabitants within 30-kilometer distance from center), and small cities/villages. In study IV and V, type of living area was determined by the degree of urbanization and was in Study IV categorized into the three groups: cities (densely populated areas), town and suburbs (intermediate density areas), and rural areas (thinly populated areas). In Study V town and suburbs, and rural areas were collapsed, and the variable was named: Living in cities categorized as yes and no.

Marital status was categorized as married, and not married (not married, divorced, and widowed).

In Study V each individual was matched with five references on the following variables: sex, age (year of birth), level of education, country of birth, and living in cities.

#### *4.3.3.1 Work-related factors*

Work-related factors were used as covariates in Study IV. Three work-related factors were included in Study IV, all measured the year before $T_0$. Occupational sector was categorized according to the Swedish Standard of Industrial Classification SNI 2007 into the following seven groups: Manufacturing, agriculture, forestry & fishing (G01, G02, G03); Construction (G04); Trade, transport, hotels & restaurants (G05, G06, G07); Finance, communication & cultural services (G08, G09, G10, G11, G12, G15); Education (G13); Health & social care (G14); Not in work/Unknown (G99). Private/public employer was categorized into three groups: private; public; Not in work/Unknown. Type of occupation, according to the Swedish Standard for Occupational Classification SSYK was categorized into the following three groups: white collar; blue collar; Not in work/Unknown.

In paid work was categorized according to the employment status (In paid work (gainful employment); not in paid work (not in gainful employment)). In study V, those not in paid work during 2014 were excluded.

#### *4.3.3.2 Comorbidity*

In Study V comorbidities were used as covariates and assessed during the year before $T_0$ ($Y_{-1}$), as having any hospitalization or specialized outpatient healthcare due to mental diagnoses (ICD-10: F00-F99); musculoskeletal diagnoses (M00-M99); or other diagnoses (other than: F00-F99, M00-M99, O80, S00-T98, and Z00-Z99). Both main and secondary diagnoses were included.

### 4.3.4 Sickness absence and disability pension

The outcomes in the studies in the thesis were SA and DP in relation to road traffic accidents. All information on SA and DP were assessed from MiDAS. In MiDAS, all SA spells and DP spells reimbursed by the Social Insurance Agency are available. For employed individuals that is SA spells from day 15, for unemployed short SA spells of 2-14 days are also available as they do not have an employer, and hence are reimbursed by the Social Insurance Agency from day two. In this thesis, in order to not introduce bias, only SA spells >14 days were included. As illustrated in Figure 2, only those seeking healthcare after an injury sustained in an accident are included in the thesis. However, SA can be granted for all individuals, not only those with inpatient or specialized outpatient healthcare.

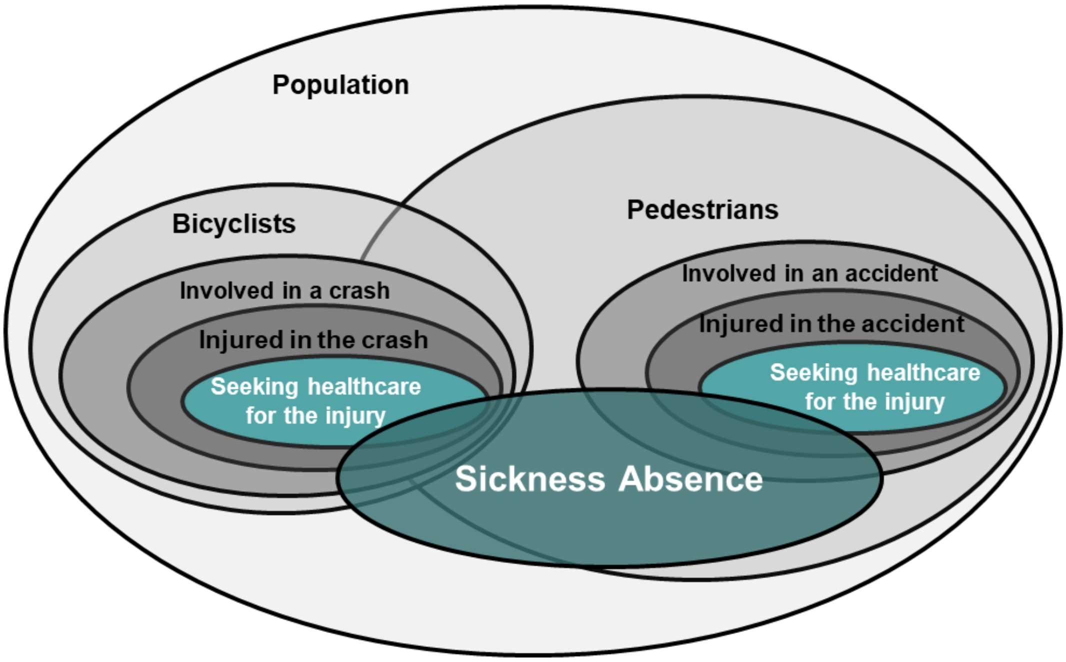


**Figure 2**. Illustration of study population for the included bicyclists and pedestrians and their risk for sickness absence (not drawn to proportion).

The individuals were identified through the date of the healthcare visit/hospitalization rather than the actual accident date. Hence, the healthcare visit/hospitalization and the start of SA does not necessarily take place on the same day (e.g., seeking healthcare some days after the accident, or starting a new SA some days later due to weekend or holiday). The distribution of SA start dates in relation to the date of the visit/hospitalization, with more SA-spell starting at the same day and days close to the visit/hospitalization, was taken into consideration when categorizing the SA and DP variables.

#### 4.3.4.1 Study I

In Study I, a cross-sectional study, SA and DP at the time of the crash, $T_{0,}$ were categorized into the following three groups: Ongoing SA/DP, New SA, and No new SA. Ongoing SA/DP included individuals with full-time DP in spells that had started before $T_0$ and were still ongoing, and individuals with SA spells (irrespective of the extent) that had started at least five days before $T_0$ and were still ongoing. New SA included individuals with SA spells that started on any day between 4 days before and 4 days after $T_0$. The group Ongoing SA/DP were excluded in the logistic regression, as they are not at risk of New SA.

#### 4.3.4.2 Study II

In Study II, SA and DP were assessed weekly for a duration of four years, and the study period was divided into 209 weeks, 52 weeks prior ($W_{-52}$) through 156 weeks after ($W_{+156}$) the week of the crash $W_0$. The week of the crash, $W_0$, was defined as $T_0$, three days before, and three days after that date (that is, seven days, centered around the date of the visit/hospitalization). Sickness absence and DP for each week were categorized into the following five non-overlapping states:

1) no SA or DP (no SA or DP during the week),
2) SA (any SA during the week, and no DP),
3) SA and DP (both SA and DP during the week),
4) part-time DP (any part-time DP, and no SA or full-time DP during the week), and
5) full-time DP (any full-time DP, and no SA during the week).

#### 4.3.4.3 Study III

In Study III, SA and DP were categorized in the same way as in study I, although Ongoing SA/DP was divided into Ongoing SA and Ongoing full-time DP. As in Study I the groups Ongoing SA and ongoing full-time DP were excluded in the logistic regression.

#### 4.3.4.4 Study IV

In Study IV, SA and DP were assessed weekly as in Study II. However, the non-overlapping states in Study IV were based upon diagnoses, in contrast to Study II where the diagnoses were not used. For each week, individuals were assigned one out of the following four non-overlapping states based on their SA situation during that week:

1) No SA or DP (no SA or DP during the week),
2) SA due to injury diagnosis (any SA due to an injury diagnosis (ICD10: S00-T98) during the week, and no DP),
3) SA due to other diagnoses (any SA due to other diagnoses than injuries, no DP, and no SA due to an injury diagnosis during the week), and
4) DP (any DP, regardless of extent or diagnosis, during the week).

Those individuals who were in state 4) DP during the whole study period (i.e., all 209 weeks) were excluded from the study.

#### 4.3.4.5 Study V

In Study V number of SA and DP net days were assessed yearly, for both those injured and their matched references during a period of five years; one year before ($Y_{-1}$) and four years ($Y_{+1}$ - $Y_{+4}$)

following $T_0$. Diagnoses of SA and DP were categorized as: Injury diagnoses (ICD10: S00-T98); and Other diagnoses (all SA except S00-T98). Furthermore, in some analyses the SA and DP diagnoses were categorized into seven groups: Injuries (S00-T98), Cancer (C00-D48), Mental diseases (F00-F99), Central Nervous System (CNS) (G00-G99), Cardiovascular disease (CVD) (I00-I99), Musculoskeletal (M00-M99), Other (all other SA).

## 4.4 Statistical analyses

In Study I, descriptive statistics in the form of frequencies and percentages were used to describe the study population in total and stratified by SA and DP status at $T_0$ (i.e. No SA, New SA and Ongoing SA/DP in connection with the crash). Logistic regression was used to estimate odds ratios (OR) and 95% confidence interval (CI) for New SA. In these analyses those with Ongoing SA/DP at the time of the crash were excluded. Crude OR and OR for several different models were calculated. The models included sociodemographic, crash, and injury characteristics.

Study III had the same set up as in Study I, the SA and DP status at $T_0$ was divided into No SA, New SA, Ongoing SA, and Ongoing full-time DP in connection with the accident. Several models of logistic regression were conducted, for all and stratified for sex.

In Study II and IV, descriptive statistics in the form of frequencies and percentages were used to describe the study population for all and stratified by sex. Weekly SA/DP states for all individuals were assessed during a four-year period, from one year before through three years following the week of the accident, $W_0$ ($W_{-52}$ to $W_{+156}$). This gives each individual a sequence of 209 weeks of SA/DP states with sequence analysis using TraMineR in R[111]. In Study II the SA/DP states focused on SA and extent of DP, whereas Study IV focused on the diagnoses of SA. The most common sequences in each study were presented in frequency plots in Study II for all, and in Study IV stratified for sex.

After forming the sequences, cluster analysis with optimal matching spell algorithm[112] was used to identify different clusters/groups of individuals who had similar sequences of SA/DP-states. A cluster tree (illustrating the branches of clusters for different numbers of clusters) and several measures of cluster partition quality[111] were used to choose the number of clusters in each study. The clusters in Study II were illustrated in density plots and plots of representative sequences showing the sequence(s) that covered at least 35% of all sequences in each cluster with a neighborhood radius of 10%. In Study IV the clusters were illustrated with density plots and index plots. Density plots shows the proportion of individuals in each state for each week, whereas in index plots each individual's sequence is represented with one line, and can be sorted, e.g., by SA/DP state from the start of the sequence. Crude and mutually adjusted multinomial logistic regressions were used to analyze the association (OR and 95% CI) between sociodemographic, type of accident, type of healthcare, type of injury, injured body region, and the different SA/DP-clusters. In addition, in study IV work-related factors were included in the model.

In Study V, descriptive statistics in the form of frequencies and percentages were used to describe the study population for all and stratified by road user group (i.e., pedestrians, bicyclists, car occupants, and other road users) and their non-injured matched references. Frequencies and percentages of injured individuals by injured body region in relation to type of injury were presented for the different road user groups. Mean SA and DP net days/year for each group and mean differences of SA and DP (i.e., excess) net days/year compared with their matched references. Excess SA and DP due to injury diagnoses and other diagnoses were calculated using independent t-tests with bootstrapped 95% CI. In addition, average SA and DP net days/year due to seven different diagnosis groups for the road user groups and their matched references were calculated.

The statistical analyses were in Study I and Study III performed using SPSS (version 22 and 26, respectively) and STATA (version 14), in Study II using R (3.5.0), Study IV and Study V using SAS (version 9.4) and R (version 3.6.1 and 4.2.1, respectively).

## 4.5 Ethical considerations

All studies in this thesis were based on pseudonymized individuals-level linked microdata obtained from several nationwide registers in Sweden and linked at individual level. The project was approved by the Regional Ethical Review Board in Stockholm, Sweden (dnr: 2007/762-31, 2009/23-32, 2009/1917-32, 2011/806-32, 2011/1710-32, 2016/1533-32). The National Board of Health and Welfare, Statistic Sweden, and the Social Insurance Agency have approved the use of these databases for research in Sweden. This sensitive data was only accessible for research purposes by eligible researchers in the project group. In the process of data acquisition and usage strict guided procedures are followed by the Swedish Ethical Review Act, the Administrative Procedure Act, the Personal Data Act, and the European General Data Protection Regulation. The data is derived directly from the registers, and hence, there is no chance of personal contact or associated risk for the participants. Because the data is pseudonymized the integrity and anonymity of the persons are secured, and the possibility of backward identification is eliminated by presenting the results at group levels and not reporting numbers if cell values are lower than eight. Taking these rigorous safety measures into account, the benefits of generating knowledge regarding SA and DP following a road traffic accident exceed the potential risks that may arise due to loss of integrity for the studied individuals.

# 5 Results

The results of the five studies are presented below.

## 5.1 Study I - Sickness absence in connection with the crash among injured bicyclists

In total, 7643 individuals aged 16-64 received in- or specialized outpatient healthcare due to a new bicycle crash in 2010. There were similar proportions of individuals in each age group, larger proportions of men (57%), individuals living in medium-sized cities (42%), individuals born in Sweden (85%), with high school or college/university education (77%), and not married (68%). Most of the individuals (72%) did not start a new SA spell in connection with the crash, nor have any ongoing SA spell >14 days or full-time DP at the time of the crash ($T_0$). In total 18% had new SA at $T_0$ and 10% were already on SA or full-time DP at $T_0$ (Table 3).

**Table 3.** Numbers and percentages of the study population, by sickness absence (SA) and disability pension (DP) status at the time of the bicycle crash, stratified by sex and age groups. Part of table 1 from Study I.

| | **Total** | | **No new SA** | | **New SA** | | **Ongoing SA/DP** | |
|---|---|---|---|---|---|---|---|---|
| | **n** | **column%** | **n** | **row%** | **n** | **row%** | **n** | **row%** |
| **Total (row%)** | 7643 | 100.0 | 5528 | 72.3 | 1367 | 17.9 | 748 | 9.8 |
| **Sex** | | | | | | | | |
| Women | 3303 | 43.2 | 2293 | 69.4 | 678 | 20.5 | 332 | 10.1 |
| Men | 4340 | 56.8 | 3235 | 74.5 | 689 | 15.9 | 416 | 9.6 |
| **Age group, years** | | | | | | | | |
| 16-24 | 1576 | 20.6 | 1461 | 92.7 | 74 | 4.7 | 41 | 2.6 |
| 25-34 | 1217 | 15.9 | 970 | 79.7 | 167 | 13.7 | 80 | 6.6 |
| 35-44 | 1580 | 20.7 | 1136 | 71.9 | 323 | 20.4 | 121 | 7.7 |
| 45-54 | 1746 | 22.8 | 1133 | 64.9 | 400 | 22.9 | 213 | 12.2 |
| 55-64 | 1524 | 19.9 | 828 | 54.3 | 403 | 26.4 | 293 | 19.2 |

An age-related trend was found with larger proportions of New SA and Ongoing SA/DP with increasing age. As mentioned above, there was a larger proportion of men among the injured bicyclists, in contrast the proportion of individuals with new SA was larger among women than among men (20.5% and 15.9%, respectively) (Table 3). The majority of the individuals, were injured in a single-bicycle crash, 6484 individuals (85%), and among those 18% had a new SA at $T_0$. The proportion with a new SA were similar for collision with pedestrian, animal, or other bicycle (19%), and collision with motor vehicle (19%). A majority of the injured bicyclists had only specialized outpatient healthcare (83%), in this group 14% had new SA. Among those with inpatient healthcare ≤1 day (8% of the individuals) 24% had new SA and among those with inpatient healthcare >1 day (9% of the individuals), 51% had new SA in connection with the bicycle crash.

External injuries and fractures were the most common injury types, accounting for 39% and 37% of all injuries, respectively. On the other hand, the injury types with the highest proportion of new SA were fractures and dislocations, where 33% and 24% had new SA in connection with the crash, respectively (Figure 3). The most commonly injured body regions were the upper extremities (43%) followed by the lower extremities (19%) and head, face, and neck, not TBI (19%). The injured body regions with the largest proportions of New SA in connection with the crash were injuries to the vertebral column and spinal cord (37%), and TBI (36%) (Figure 3).

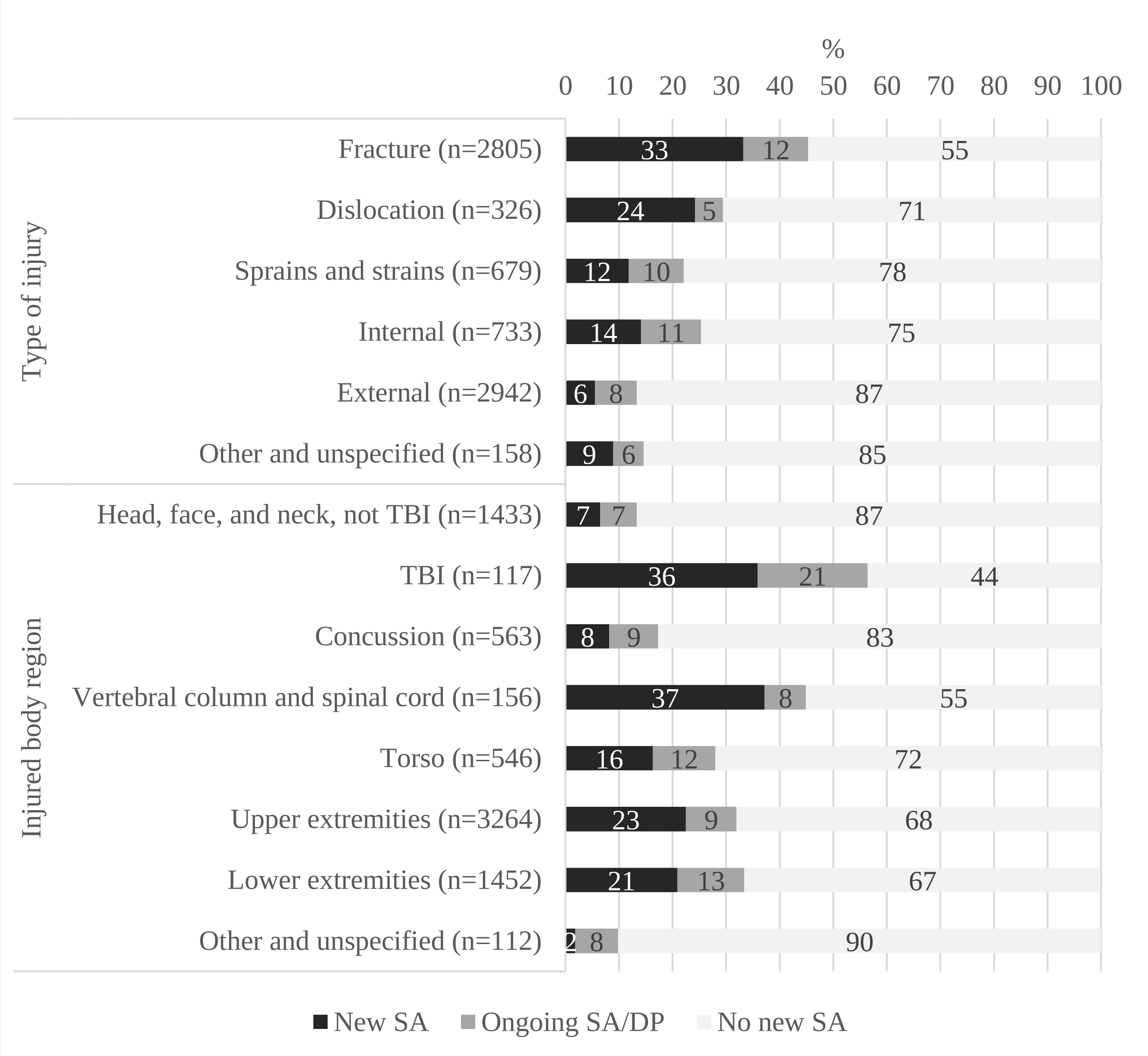


**Figure 3**. Proportion of individuals with New SA, Ongoing SA/DP, and No new SA, respectively, by type of injury and injured body region.
Abbreviations: SA: Sickness absence, DP: Disability pension, TBI: Traumatic brain injury

Those with ongoing SA or full-time DP at $T_0$ (i.e., those not at risk of new SA) were excluded in the analysis of OR of New SA, leaving 6895 individuals for the analyses. The adjusted OR for a New SA among women was 1.55 (95% CI 1.34–1.78) compared with men. The OR for New SA was higher among older individuals. Having had in-patient healthcare >1 day was strongly associated with New SA both in crude analyses (OR 8.47; 95% CI 7.04–10.18) and fully adjusted for sociodemographic, injury- and crash-related factors (OR 7.54; 95% CI 6.20–9.17). In addition, higher OR for New SA was observed for collision with motor vehicle compared with single bicycle crashes in the fully adjusted model.

Logistic regression was conducted for crude and five models with adjusted OR for type of injury and injured body region. Crude OR and two of these models (model 4 and model 5) are presented in Table 4.

In model 4 type of injury and injured body region were separately adjusted for age, sex, level of education, country of birth, type of living area, marital status, and type of crash, while in model 5 they were further adjusted for each other, i.e., both type of injury and injured body region were included in the same model.

**Table 4.** Crude and adjusted odds ratios with 95% confidence intervals for new sickness absence (SA) following a bicycle crash. Part of table 4 in Study I.

| | **All at risk of SA[1]** | **Crude** | **Model 4[2]** | **Model 5[3]** |
|---|---|---|---|---|
| | **n (% SA)** | **OR (95% CI)** | **OR (95% CI)** | **OR (95% CI)** |
| **Type of injury** | | | | |
| Fracture | 2465 (37.7) | 9.60 (8.03-11.48) | 9.74 (8.09-11.73) | 8.04 (6.62-9.77) |
| Dislocation | 309 (25.6) | 5.44 (4.03-7.35) | 5.48 (4.00-7.49) | 4.36 (3.15-6.05) |
| Sprains and strains | 609 (13.1) | 2.40 (1.80-3.18) | 2.62 (1.96-3.51) | 1.77 (1.31-2.40) |
| Internal | 651 (15.8) | 2.98 (2.29-3.88) | 3.04 (2.32-3.99) | 7.34 (3.67-14.66) |
| External | 2712 (5.9) | ref. | ref. | ref. |
| Other and unspecified | 149 (9.4) | 1.64 (0.93-2.91) | 1.62 (0.90-2.90) | 2.83 (1.51-5.31) |
| **Injured body region** | | | | |
| Head, face, and neck, not TBI | 1335 (7.0) | ref. | ref. | ref. |
| TBI | 93 (45.2) | 11.00 (6.95-17.41) | 9.40 (5.81-15.20) | 2.72 (1.19-6.22) |
| Concussion | 512 (9.0) | 1.32 (0.91-1.91) | 1.36 (0.93-1.98) | 0.38 (0.18-0.83) |
| Vertebral column and spinal cord | 144 (40.3) | 9.01 (6.07-13.36) | 9.06 (5.98-13.72) | 3.53 (2.24-5.55) |
| Torso | 482 (18.5) | 3.02 (2.21-4.13) | 2.66 (1.93-3.66) | 1.48 (1.04-2.11) |
| Upper extremities | 2956 (24.8) | 4.40 (3.51-5.52) | 4.48 (3.55-5.65) | 2.09 (1.61-2.70) |
| Lower extremities | 1270 (23.9) | 4.20 (3.28-5.38) | 4.05 (3.14-5.22) | 2.81 (2.12-3.72) |
| Other and unspecified | 103 (1.9) | 0.26 (0.06-1.09) | 0.29 (0.07-1.18) | 0.29 (0.07-1.29) |

[1] N = 6895, i.e., excluding those already on SA or full-time disability pension, among all individuals in Sweden of working ages who in 2010 had a new bicycle crash leading to in- or specialized outpatient healthcare

[2] Adjusted for age, sex, level of education, country of birth, type of living area, marital status, and type of crash.

[3] Adjusted for age, sex, level of education, country of birth, type of living area, marital status, type of crash, type of injury, and injured body region.

Abbreviations: SA: Sickness absence, OR: Odds ratio, CI: Confidence interval, TBI: Traumatic brain injury, ref.: Reference category

When adjusting for sociodemographic factors and type of crash (Model 4), the results did not differ substantially from the crude ORs. However, after also mutually adjusting for type of injury and injured body region (model 5), a larger difference can be seen. For internal injuries, the OR increased from about 3 in crude and model 4 to 7.3 in model 5. For TBI and vertebral column and spinal cord, the opposite was seen, with decreasing OR from 9.4 and 9.1 in crude and model 4 to about 2.7 and 3.5 in model 5, respectively. The OR for lower extremities and upper extremities were 2.81 (95% CI 2.12-3.72) and 2.09 (95% CI 1.61-2.70) in the fully adjusted model, respectively. Individuals with fractures had eight times higher adjusted OR for New SA compared with individuals with external injuries in the fully adjusted model.

## 5.2 Study II - Sickness absence and disability pension in a longer perspective among injured bicyclists

In Study II, the individuals were followed according to weekly SA and DP states during one year before and three years following the bicycle crash (i.e., 209 weeks). Seven clusters of sequences of weekly SA and DP states were identified using sequence and cluster analysis methods:
1. “No SA or DP” (58.2% of the cohort),
2. “Low SA or DP” (7.4%),
3. “Immediate SA” (20.3%),
4. “Episodic SA” (5.9%),
5. “Long-term SA” (1.7%),
6. “Ongoing part-time DP” (1.7%), and
7. “Ongoing full-time DP” (4.8%).

All clusters had different characterizations of SA and DP patterns during the four studied years: the representative sequence(s), visualizing these patterns and their homogeneity/heterogeneity are shown in Figure 4.

The largest and most homogenous cluster was “No SA or DP”. One representative sequence with only the state no SA or DP during all weeks, covered (with a neighborhood radius of 10%) 100% of the sequences in this cluster. In this cluster 62% were men, 59% were 18-40 years old, 84% were born in Sweden, 41% had university/college education, 38% were living in big cities, 30% were married, 89% had no inpatient healthcare at $T_0$, 85% were injured in a single bicycle crash, 47% had external injuries, and 24% had injuries to the head, face, and neck, not TBI. This cluster, and the here mentioned categories were used as reference groups in the mutually adjusted multinomial logistic regression.

In the cluster “Low SA or DP”, two representative sequences, with only a couple of weeks of SA during the follow-up, represented 50% of the sequences in that cluster.

In the cluster “Immediate SA”, one representative sequence, with SA starting in direct connection with the week of the crash, and ending a couple of months after, represented 80% of the sequences in that cluster.

The cluster “Episodic SA” was a heterogenous cluster with four representative sequences covering 44% of the sequences in that cluster. All four representative sequences started SA in connection with the week of the crash, one had SA for over one year, the other three had a short SA spell starting at the week of the crash but also recurring events of SA later during the follow-up.

The cluster “Long-term SA” was even more heterogenous: here six representative sequences were identified, yet combined they covered only 36% of the sequences in that cluster. All six representative sequences contained long periods of SA, with varying starting points: before the crash, at the crash, and a year after the crash. One of the representative sequences that started SA in connection with the crash transitioned to full-time DP after two years and remained at full-time DP during the rest of the follow-up.

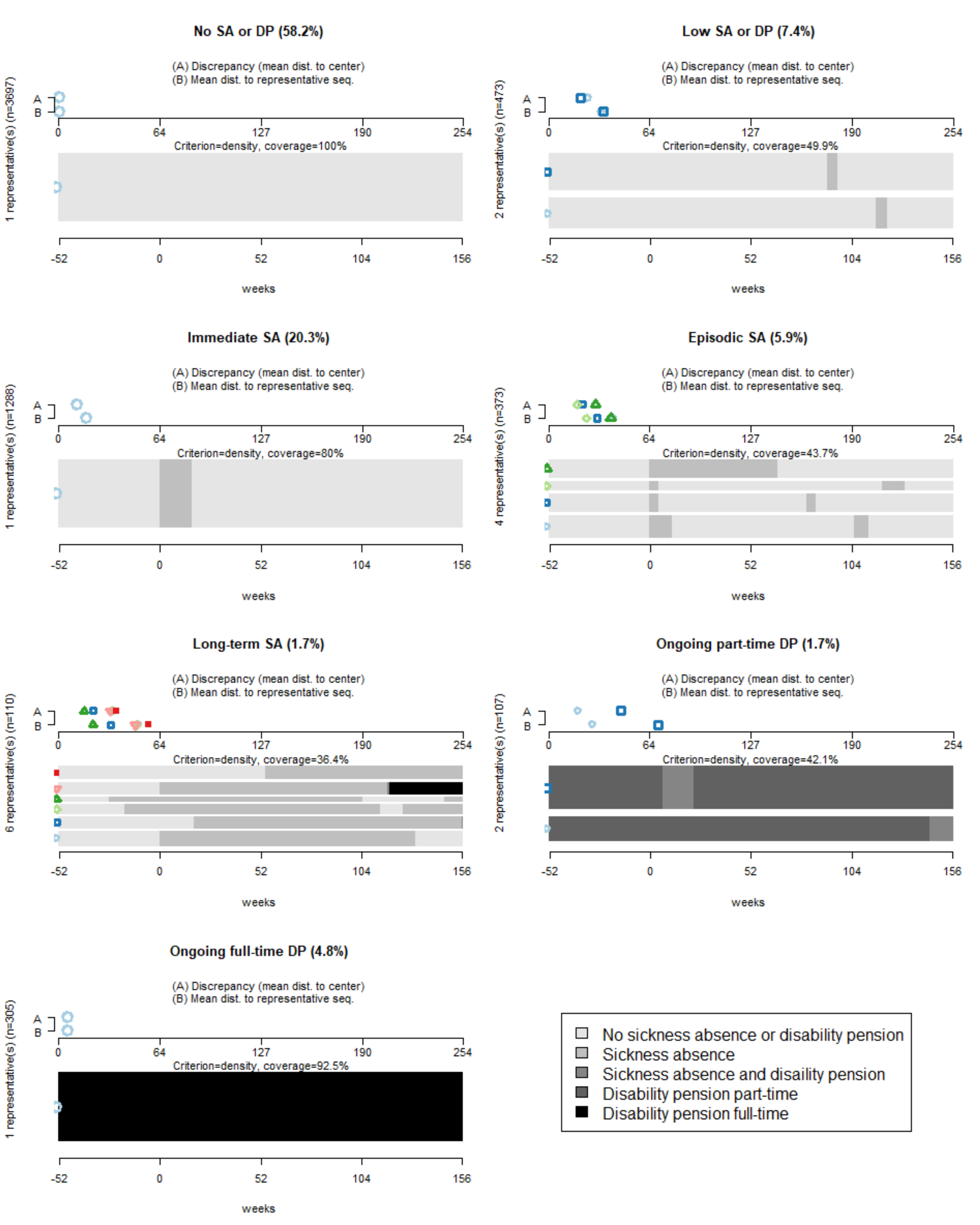


**Figure 4**. Representative sequence(s) that with a neighborhood radius of 10% covered at least 35% of all sequences of sickness absence (SA) and/or disability pension (DP) states/week during one year before through four years after the week of the bicycle crash (marked with 0 in the figure), in each of the seven identified clusters. The width of the bars is proportional to the number of sequences in each representative sequence. The scales in the top of each cluster represent, for each representative sequence; A: discrepancy (mean distance to the center) and; B: the mean distance to the representative sequence.

In the cluster “Ongoing part-time DP” the individuals had part-time DP during the whole follow-up, from one year before through three years after the crash, some individuals with part-time DP had combined SA and DP during a couple of months in connection with the crash. These two representative sequences represented 42% of the sequences in that cluster.

In the cluster "Ongoing full-time DP" one representative sequence, with full-time DP during all four years, represented 93% of the sequences in that cluster.

Compared to the cluster "No SA or DP", all other clusters have higher proportions of women, individuals in the age group 41-59 years, and individuals with high school education. All clusters, except "Low SA or DP", had a higher proportion of hospitalization at $T_0$ compared to the cluster "No SA and DP". The proportions of type of injury in each cluster are shown in Figure 5. External injuries were the most common type of injury in the clusters "No SA or DP", and "Low SA or DP", and had its smallest proportion in the cluster "Immediate SA". Fractures were the most common type of injury in the clusters "Immediate SA" and "Episodic SA". The largest proportion of internal injuries was in the cluster "Long-term SA".

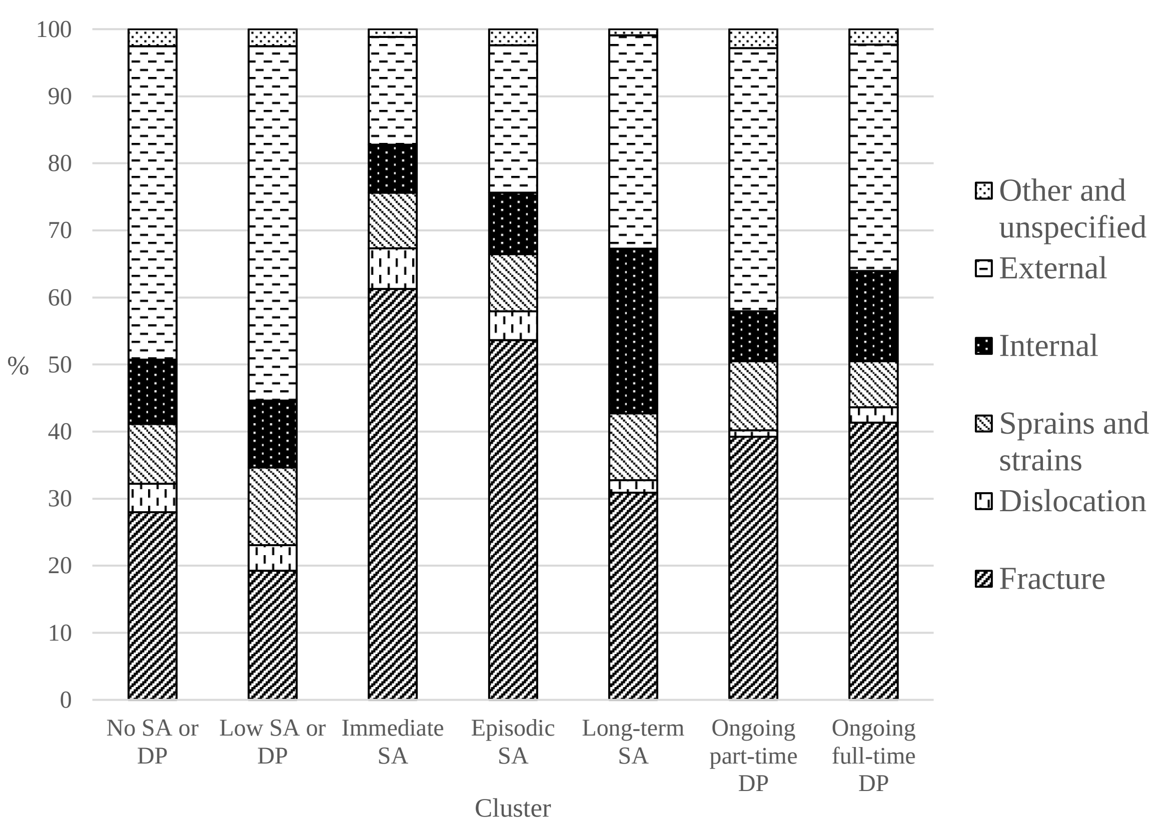


**Figure 5**. Proportions of types of injuries within each cluster.
Abbreviations: SA: Sickness absence, DP: Disability pension

The proportions of injured body regions in each cluster are shown in Figure 6. The most common injured body region in all the clusters were upper extremities, ranging between 34% and 54% of the injuries in the different clusters. The clusters "Immediate SA" and "Episodic SA" had the highest proportion of injuries to the upper extremities.

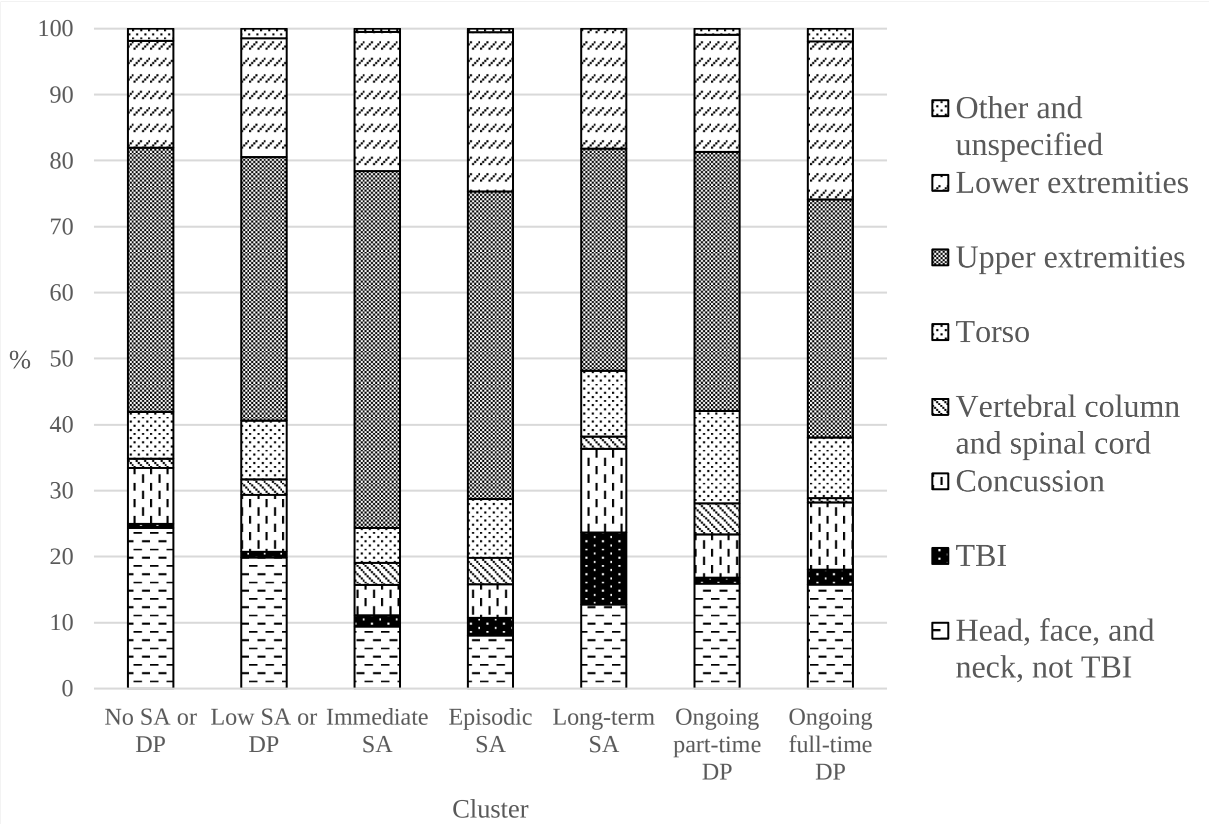


**Figure 6**. Proportions of injured body regions within each cluster.
Abbreviations: SA: Sickness absence, DP: Disability pension, TBI: Traumatic brain injury

The proportion of TBI was largest in the cluster “Long-term SA” 11%, in the other clusters, this proportion ranged between 0,6% and 2,7%. The OR for TBI in the cluster “Long-term SA” was 18.4 (95% CI: 2.2-155.2).

## 5.3 Study III - Sickness absence in connection with the accident among injured pedestrians

In total, 5576 pedestrians aged 16-64 received in- or specialized outpatient healthcare due to injuries caused by a new traffic-related accident in 2010. Among the injured pedestrians, a higher proportion were in the older age groups and a somewhat higher proportion were women (56%). A majority were born in Sweden (84%), were not married (65%), and had high school or college/university education (74%). Most of the pedestrians (61%) did not have an ongoing SA spell >14 days or full-time DP at $T_0$, nor begin a new SA spell at $T_0$, while 20% had a new SA spell, 8% had ongoing SA and 11% had ongoing full-time DP (Table 5). An age-related trend was found for all three categories, with higher proportion of new SA and ongoing SA and fulltime DP with increasing age. Furthermore, having a new SA spell was more common among women, married individuals, and among those with ongoing part-time DP. The adjusted OR for a new SA among women compared with men was 1.25 (95% CI 1.06-1.49). The OR for new SA was higher among older pedestrians compared to younger.

**Table 5.** Numbers and percentages of the study population, by sickness absence (SA) and disability pension (DP) status at the time of the accident, stratified by sex and age groups. Part of table 1 from Study III.

| | **Total** | | **No new SA** | | **New SA** | | **Ongoing SA** | | **Ongoing full-time DP** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **n** | **column %** | **n** | **row %** | **n** | **row %** | **n** | **row %** | **n** | **row %** |
| **Total (row%)** | 5576 | 100 | 3424 | 61.4 | 1130 | 20.3 | 420 | 7.5 | 602 | 10.8 |
| **Sex** | | | | | | | | | | |
| Women | 3134 | 56.2 | 1800 | 57.4 | 733 | 23.4 | 257 | 8.2 | 344 | 11.0 |
| Men | 2442 | 43.8 | 1624 | 66.5 | 397 | 16.3 | 163 | 6.7 | 258 | 10.6 |
| **Age group, years** | | | | | | | | | | |
| 16-24 | 1076 | 19.3 | 950 | 88.3 | 70 | 6.5 | 33 | 3.1 | 23 | 2.1 |
| 25-34 | 701 | 12.6 | 501 | 71.5 | 116 | 16.5 | 51 | 7.3 | 33 | 4.7 |
| 35-44 | 923 | 16.6 | 577 | 62.5 | 207 | 22.4 | 81 | 8.8 | 58 | 6.3 |
| 45-54 | 1232 | 22.1 | 623 | 50.6 | 325 | 26.4 | 107 | 8.7 | 177 | 14.4 |
| 55-64 | 1644 | 29.5 | 773 | 47.0 | 412 | 25.1 | 148 | 9.0 | 311 | 18.9 |

The two most common accident types were pedestrian falls related to snow and ice (36%) and falls related to slipping, tripping, and stumbling (28%). These two groups and collision with motor vehicle were the type of accident with the highest proportion of new SA (Figure 7). All types of falls accounted for 75% of the accidents.

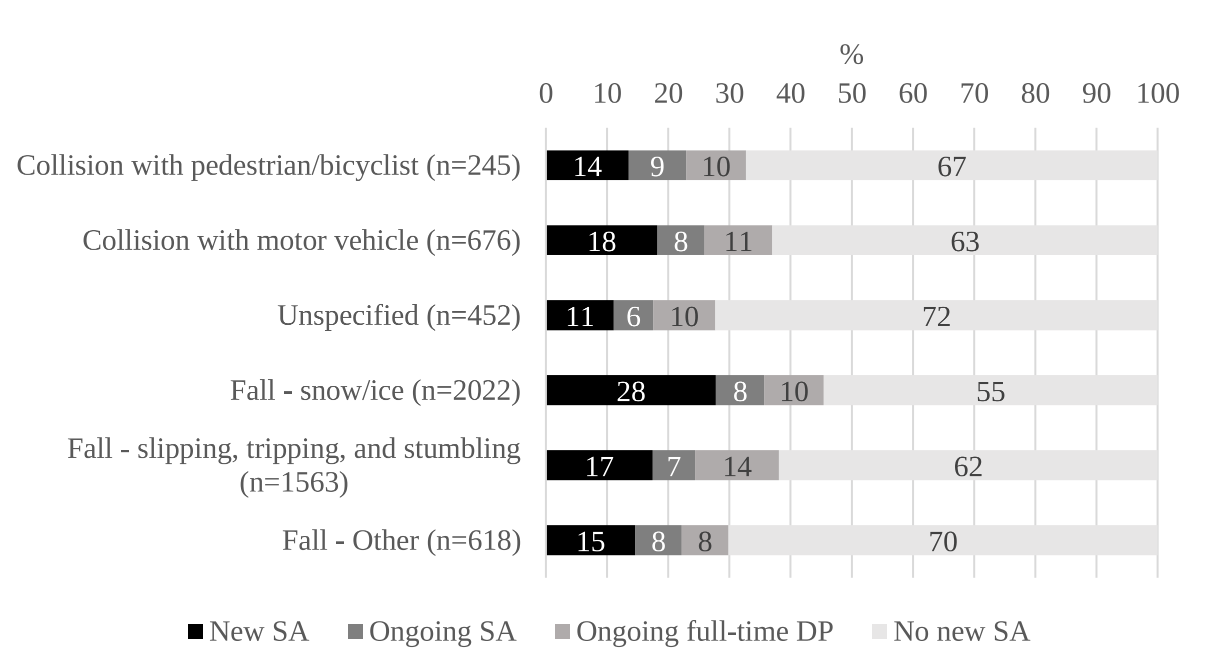


**Figure 7**. Proportions of individuals with New SA, Ongoing SA, Ongoing full-time DP, and No new SA, respectively, by type of accident. Abbreviations: SA: Sickness absence, DP: Disability pension.

A fall related to snow and ice and collision with motor vehicle was associated with higher OR of a new SA compared with a fall related to slipping, tripping, and stumbling in the logistic regression. When stratified for sex, the association for falls related to snow and ice was significant for women but not for men.

Fractures and external injuries were the most common injury types, accounting for 45% and 30% of all injuries, respectively. Beginning a new SA spell was most common among pedestrians with a fracture (36% had a new SA) and least common for external injuries (5% had a new SA) (Figure 8). Fractures had a 10-times higher adjusted OR for new SA compared with external injuries. In the sex-stratified analyses, both women and men had higher ORs for new SA if they had a fracture, a dislocation, or an internal injury. In addition, men had higher ORs for a new SA if they had sprains and strains.

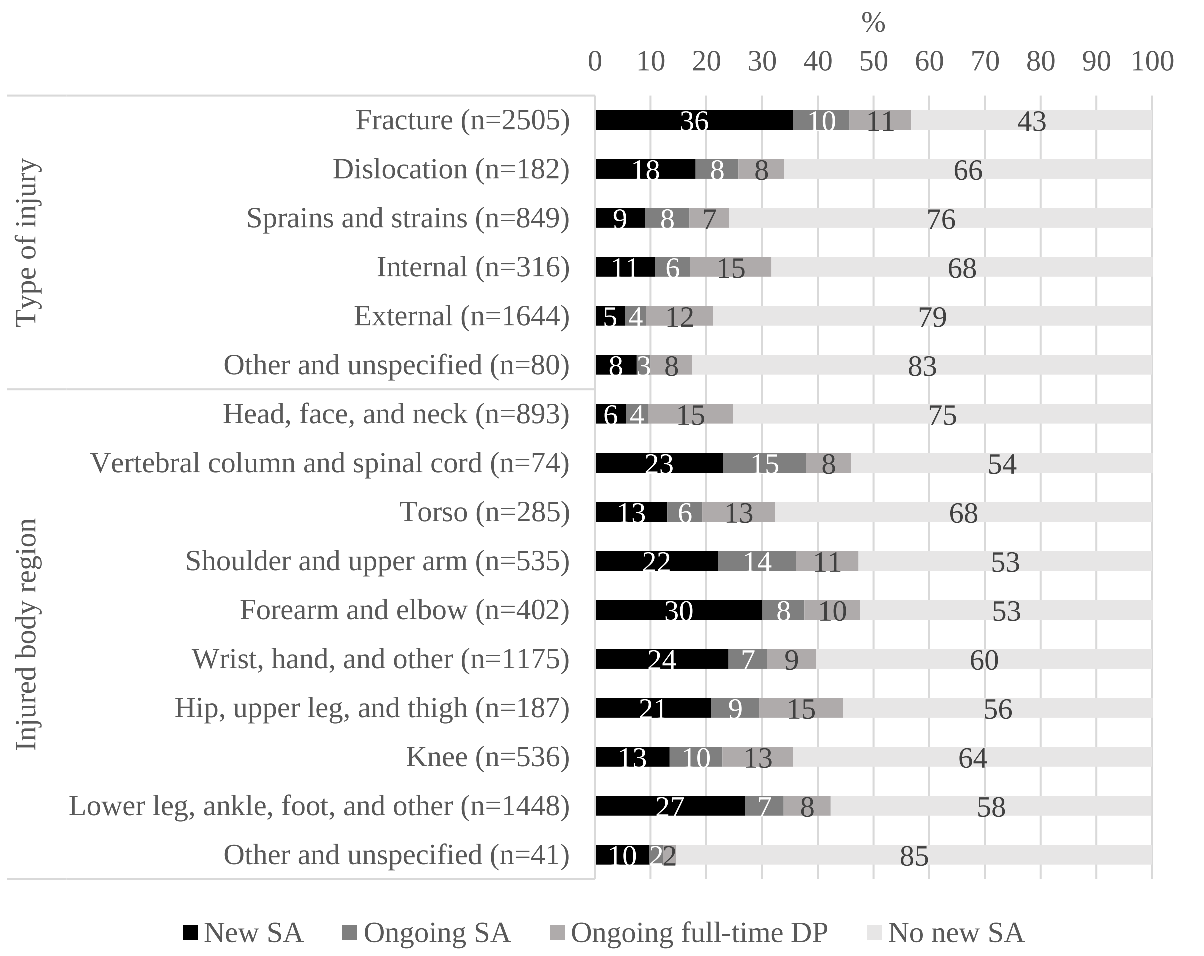


**Figure 8**. Proportions of individuals with New SA, Ongoing SA, Ongoing full-time DP, and No new SA, respectively, by types of injury and injured body region. Abbreviations: SA: Sickness absence, DP: Disability pension.

The most commonly injured body regions were upper and lower extremities with most injuries in the subgroup lower leg, ankle, foot, and other leg (26%) followed by the wrist, hand, and other arm (21%). Head, face, and neck stood for 16% of all injuries. New SA was most common among pedestrians with injuries to the forearm and elbow (30%) (Figure 8).

All body regions had higher ORs for new SA compared to the category: head, face, and neck. Highest ORs were seen in the three categories: shoulder and upper arm; hip, upper leg and thigh; and lower leg, ankle, foot, and other leg.

The majority of the pedestrians, 82%, had only specialized outpatient healthcare, in this group 16% had new SA. Among those with inpatient healthcare <3 days the proportion with a new SA spell was 29%

and among those with inpatient healthcare ≥3 days the proportion with new SA was 46%. This is also reflected in the ORs: having had inpatient healthcare ≥3 days was associated with new SA both in the crude analysis OR 6.63 (95% CI 5.42-8.11) and after adjusting for sociodemographic factors and for accident- and injury-related factors (OR 3.65 (95% CI 2.82-4.73)). The association for inpatient care <3 days was smaller, but still significant (crude OR 2.40 (95% CI 1.88-3.07), adjusted OR 3.20 (95% CI 2.34-4.39)).

## 5.4 Study IV - Sickness absence and disability pension in a longer perspective among injured pedestrians

In total, there were 11,432 pedestrians aged 20-59 years with in- or specialized outpatient healthcare due to a new traffic accident including fall accidents 2014-2016. The most common types of accident were falls related to slipping, tripping, and stumbling, followed by falls related to snow and ice. The most common types of injuries were fractures, external injuries, and sprains and strains. A quarter of the injured pedestrians worked in Finance, communication & cultural services. Among women, 29% worked in Health & social care and 14% worked in Trade, transport, hotels & restaurants; the corresponding numbers in men were 5%, and 24% respectively.

The pedestrians were followed according to weekly SA status for four years, one year before and three years following the accident, and diverse patterns of SA during the study period were observed among the pedestrians. The number of unique sequences was 4358. The by far most common sequence observed, for both women and men, was to have no SA or DP during all 209 weeks ($W_{-52}$ to $W_{+156}$) (39% for women and 53% for men). Several of the most common sequences included no SA prior to the accident and SA of various durations due to injury diagnoses starting from the week of the accident ($W_0$).

Cluster analysis was used to form groups of individuals who had similar sequences. Eight clusters were identified:

1. "No SA" (including 47% of the study population),
2. "Immediate SA" (18%),
3. "Episodic SA" (4%),
4. "Long-term or later SA" (3%),
5. "Both SA due to injury and other diagnoses" (7%),
6. "Other diagnoses short-term SA" (17%),
7. "Other diagnoses long-term SA" (2%), and
8. "Disability pension" (3%).

The eight clusters are illustrated using index plots in Figure 9, visualizing these sequences and their homogeneity/heterogeneity.

The largest cluster was "No SA", where almost all the individuals were not on SA or DP during the entire study period. In this cluster 53% were men, 22% were 25-34 years old, 37% had university/college education, 78% were born in Sweden, 46% were living in cities, 33% were married, 36% were injured in a fall – slipping, tripping, and stumbling, 92% had no inpatient healthcare at $T_0$, 41% had external injuries, 26% had injuries to the head, face, and neck, not TBI, 21% were injured during the summer, 31% were injured in 2014, 27% worked in Finance, communication & cultural services, 50% worked in private sector, and 37% were white collar workers. This cluster, and the here mentioned categories were used as reference groups in the mutually adjusted multinomial logistic regression.

All clusters were associated with older age, no university education, having been hospitalized, and working in Health & social care. Blue-collar work was associated with all clusters but "Disability pension".

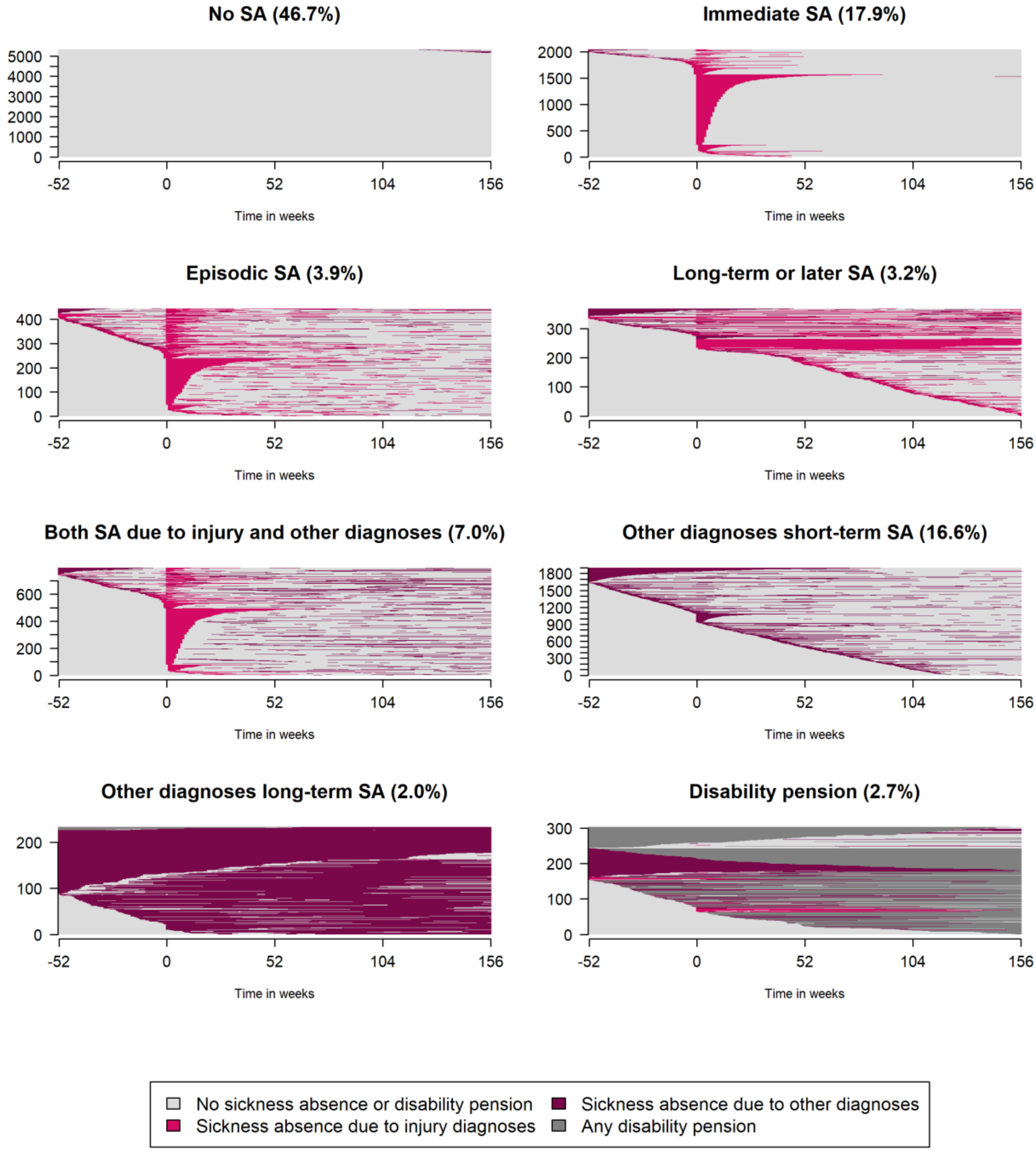


**Figure 9**. Index plots of sickness absence (SA) states/week during the year before through three years after ($W_{-52}$ to $W_{+156}$) the week of the pedestrian accident (marked with 0 in the figure), for the eight identified clusters. Every line represents one individual. The sequences in each cluster are ordered by state from the start of the sequences. Figure 3 in Study IV.

The cluster “Immediate SA” consisted of 2046 individuals and was characterized by SA due to injury diagnoses in connection with the accident. This cluster consisted of more women, more individuals born in Sweden, married, and living in towns or rural areas. A higher proportion of them worked in Construction, Trade, transport, hotels & restaurants, and Health & social care, and more of them had fractures and injuries to upper and lower extremities. This cluster was associated with collision with motor vehicle and fall: slipping tripping and stumbling (OR (95% CI): 1.54 (1.26-1.87), and 1.25 (1.05-1.48) respectively).

The cluster “Episodic SA” consisted of 445 individuals and was characterized by two or more SA spells due to injury diagnoses, one at the time of the accident and one prior to or later during the study period. This cluster consisted of more women and older individuals, and a higher proportion of them were married, and living in towns or rural areas. More of them worked in Construction, and Health & social care, more of them had blue-collar work, and more of them had fractures and injuries to upper and lower extremities. Fractures, and injuries to the upper and lower extremities had 4-fold ORs for this cluster.

The cluster “Long-term or later SA” consisted of 369 individuals and was characterized by one or several SA spells due to injury diagnoses later during follow-up. This cluster consisted of a higher proportion of men and older individuals, and more of them were married, born in Sweden, and with lower levels of education. More of them worked in Health & social care, had blue-collar work and more of them had external injuries and injuries to vertebral column & spinal cord (3.13 (1.59-6.15)). This cluster was associated with injuries sustained in a collision with pedestrian/bicyclists (1.60 (1.03 - 2.48)).

The cluster “Both SA due to injury and other diagnoses” consisted of 796 individuals and was characterized by one SA spell due to an injury diagnosis starting in connection with the accident as well as one or several SA spells due to other diagnoses during the study period. This cluster consisted of a higher proportion of women and older individuals, and more of them were married, born in Sweden, and living in towns or rural areas. More of them worked in Education (1.48 (1.08-2.02)), and Health & social care and had white-collar work, and more of them had fractures and injuries to upper and lower extremities. This cluster was associated with injuries sustained in a collision with pedestrian/bicyclists (1.70 (1.18 - 2.45)) and with the injuries: fractures, dislocations, sprains and strains, and internal injuries.

The cluster “Other diagnoses short-term SA” consisted of 1901 individuals and was characterised by one or several short-term SA spells due to other diagnoses spread out during the study period. This cluster consisted of a higher proportion of women, and individuals born in Sweden. More of them worked in Education (1.45 (1.16-1.80)), and Health & social care, and more of them had injuries to torso and vertebral column & spinal cord.

The cluster “Other diagnoses long-term SA” consisted of 233 individuals and was characterized by long-term SA due to other diagnoses. This cluster consisted of a higher proportion of women and older individuals, more of them were born in Sweden, living in cities, and with lower levels of education. A higher proportion were working in Health & social care and had unknown work or were not working.

The cluster “Disability pension” consisted of 303 individuals and was characterized by having DP. This cluster consisted of a higher proportion of both younger and older individuals, more of them were unmarried, living in towns or rural areas, and with lower levels of education. A higher proportion of them were working in Health & social care and had unknown work or was not working. A higher proportion had internal injuries and injuries to head, face, and neck.

## 5.5 Study V - Excess sickness absence and disability pension among individuals injured in road traffic accidents compared to matched references

In study V, there were 20,177 working individuals aged 20-59 years with in- or specialized outpatient healthcare due to a new traffic accident including fall accidents 2015. They were all matched to five references each, providing 100,885 matched references. A third of the injured road users were bicyclists, 16% pedestrians (including fall accidents), 31% car occupants, and 19% were other road users (82% of the other road users were motorcyclists/mopeds). More of the injured pedestrians and bicyclists were in the older age group. A higher proportion of the pedestrians were women. A higher proportion of bicyclists, car occupants and other road user were men, especially among other road users where 85% were men.

In total, the most commonly injured body regions were head, face and neck, not TBI and injuries to the wrist, hand, and other arm. The most common injury types were external injuries and fractures (Table 6). However, the injured body region and type of injuries varied among the road user groups.

**Table 6.** Injured body region and type of injury by road user group. Part of table 2 from Study V.

| | Pedestrians | Bicyclists | Car occupants | Other road users | All injured |
|---|---|---|---|---|---|
| | n (%) | n (%) | n (%) | n (%) | n (%) |
| **Total** | 3 211 (15.9) | 6 997 (34.7) | 6 221 (30.8) | 3 748 (18.6) | 20 177 (100) |
| **Injured body region** | | | | | |
| Head, face, and neck, not TBI | 406 (12.6) | 1 282 (18.3) | 1 740 (28.0) | 292 (7.8) | 3 720 (18.4) |
| TBI | 43 (1.3) | 80 (1.1) | 48 (0.8) | 37 (1.0) | 208 (1.0) |
| Concussion | 200 (6.2) | 440 (6.3) | 246 (4.0) | 139 (3.7) | 1 025 (5.1) |
| Vertebral column and spinal cord | 67 (2.1) | 171 (2.4) | 2 075 (33.4) | 271 (7.2) | 2 584 (12.8) |
| Torso | 193 (6.0) | 575 (8.2) | 1 042 (16.7) | 517 (13.8) | 2 327 (11.5) |
| Shoulder and upper arm | 285 (8.9) | 1 230 (17.6) | 301 (4.8) | 659 (17.6) | 2 475 (12.3) |
| Forearm and elbow | 223 (6.9) | 683 (9.8) | 89 (1.4) | 160 (4.3) | 1 155 (5.7) |
| Wrist, hand, and other arm | 640 (19.9) | 1 381 (19.7) | 305 (4.9) | 568 (15.2) | 2 894 (14.3) |
| Hip, upper leg, and thigh | 89 (2.8) | 203 (2.9) | 76 (1.2) | 143 (3.8) | 511 (2.5) |
| Knee | 295 (9.2) | 453 (6.5) | 123 (2.0) | 388 (10.4) | 1 259 (6.2) |
| Lower leg, ankle, foot, and other leg | 757 (23.6) | 462 (6.6) | 137 (2.2) | 546 (14.6) | 1 902 (9.4) |
| Other and unspecified | 13 (0.4) | 37 (0.5) | 39 (0.6) | 28 (0.7) | 117 (0.6) |
| **Type of injury** | | | | | |
| External | 991 (30.9) | 2 701 (38.6) | 3 009 (48.4) | 1 227 (32.7) | 7 928 (39.3) |
| Fractures | 1 336 (41.6) | 2 666 (38.1) | 601 (9.7) | 1 536 (41.0) | 6 139 (30.4) |
| Dislocation | 99 (3.1) | 353 (5.0) | 43 (0.7) | 145 (3.9) | 640 (3.2) |
| Sprains and strains | 493 (15.4) | 591 (8.4) | 2 049 (32.9) | 510 (13.6) | 3 643 (18.1) |
| Internal | 252 (7.8) | 589 (8.4) | 352 (5.7) | 245 (6.5) | 1 438 (7.1) |
| Other and unspecified | 40 (1.2) | 97 (1.4) | 167 (2.7) | 85 (2.3) | 389 (1.9) |

Abbreviations: TBI: Traumatic brain injury

Pedestrians had a higher proportion of fractures and injuries to the lower leg, ankle, and foot. Bicyclists had a higher proportion of injuries to the upper extremities. Car occupants had higher proportions of injuries to the head, face and neck, and to the vertebral column and spinal cord and had a lower proportion of fractures and a higher proportion of external injuries and sprains and strains injuries. Other road users had a lower proportion of injuries to the head, face and neck, and a higher proportion of fractures.

A more complete picture of the injuries is seen by setting the injured body region in relation to type of injury, for the different road user groups. Pedestrians had most injuries in the combinations fractures to the wrist, hand, and other arm and fractures to the lower leg, ankle, foot, and other leg, followed by external injuries to the head, face, and neck, not TBI. Furthermore, sprains and strains to the lower leg, ankle, foot, and other leg were common among the pedestrians (Table 7). Among bicyclists, the most common injury-combination were external injuries to the head, face, and neck, not TBI, and fracture to all three categories of upper extremities. Car occupants had most injuries in the injury combinations sprains and strains in the vertebral column and spinal cord (including whiplash), and external injuries to the head, face, and neck, not TBI. External injuries to the torso were also quite common, whereas there were low numbers of injuries in all other combinations. Among other road users, fractures to the shoulder and upper arm, to the wrist, hand, and other arm and to the lower leg, ankle, foot, and other leg were most common.

**Table 7.** Injured body region by type of injury among pedestrians and bicyclists respectively.

| **Pedestrians** | Fractures | Dislocation | Sprains and strains | Internal | External | Other and unspecified |
|---|---|---|---|---|---|---|
| TBI | | | | 43 (1.3) | | |
| Concussion | | | | 200 (6.2) | | |
| Head, face, and neck, not TBI | 45 (1.4) | <8 | <8 | | 333 (10.4) | 21 (0.7) |
| Vertebral column and spinal cord | 37 (1.2) | <8 | 27 (0.8) | <8 | | |
| Torso | 72 (2.2) | | <8 | <8 | 109 (3.4) | <8 |
| Shoulder and upper arm | 138 (4.3) | 58 (1.8) | 16 (0.5) | | 72 (2.2) | <8 |
| Forearm and elbow | 142 (4.4) | <8 | <8 | | 69 (2.1) | |
| Wrist, hand, and other arm | 416 (13.0) | 14 (0.4) | 85 (2.6) | | 121 (3.8) | <8 |
| Hip, upper leg, and thigh | 37 (1.2) | | 12 (0.4) | | 40 (1.2) | |
| Knee | 58 (1.8) | 10 (0.3) | 108 (3.4) | | 119 (3.7) | |
| Lower leg, ankle, foot, and other leg | 391 (12.2) | <8 | 235 (7.3) | | 117 (3.6) | 8 (0.2) |
| Other and unspecified | | | | | 11 (0.3) | <8 |
| **Bicyclists** | Fractures | Dislocation | Sprains and strains | Internal | External | Other and unspecified |
| TBI | | | | 80 (1.1) | | |
| Concussion | | | | 440 (6.3) | | |
| Head, face, and neck, not TBI | 183 (2.6) | <8 | <8 | | 1017 (14.5) | 73 (1.0) |
| Vertebral column and spinal cord | 98 (1.4) | <8 | 68 (1.0) | <8 | | |
| Torso | 222 (3.2) | | <8 | 65 (0.9) | 279 (4.0) | <8 |
| Shoulder and upper arm | 626 (8.9) | 244 (3.5) | 59 (0.8) | | 298 (4.3) | <8 |
| Forearm and elbow | 436 (6.2) | 33 (0.5) | 15 (0.2) | | 199 (2.8) | |
| Wrist, hand, and other arm | 736 (10.5) | 63 (0.9) | 226 (3.2) | | 352 (5.0) | <8 |
| Hip, upper leg, and thigh | 56 (0.8) | | 8 (0.1) | | 136 (1.9) | <8 |
| Knee | 75 (1.1) | <8 | 111 (1.6) | | 263 (3.8) | |
| Lower leg, ankle, foot, and other leg | 234 (3.3) | <8 | 94 (1.3) | | 130 (1.9) | <8 |
| Other and unspecified | | | | | 27 (0.4) | 10 (0.1) |

Abbreviations: TBI: Traumatic brain injury

Comorbidity was more common among those injured in a road traffic accident compared to their references. Six percent of pedestrians and car occupants had in- or specialized outpatient healthcare due to mental diagnoses the year before the accident, twice that of their matched references (3%). On average, nine percent among those injured in a road traffic accident had healthcare due to musculoskeletal diagnoses the year before the accident, while the corresponding number for the references was six percent.

Pedestrians and other road users were the road user groups with the most excess SA net days during the first year following the accident (38 days/year, and 40 days/year respectively) (Figure 10). The second year after the accident pedestrians and car occupants had the highest number of excess SA net days (12 and 15 days/year, respectively) as in the third and fourth year after the accident. In addition, these two road user groups had the most excess SA the year before the accident (9 and 8 days/year, respectively). The matched references had 8-13 net days of SA per year, during the whole study period.

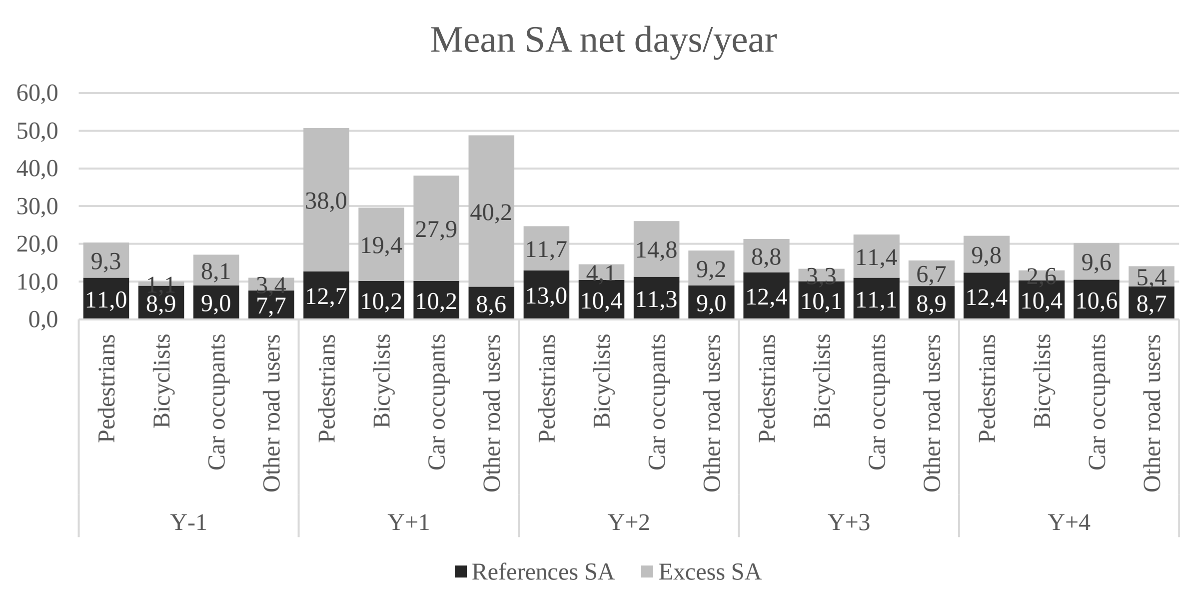


**Figure 10**. Average net days/year of sickness absence (SA) for the references and excess SA for the injured in the different road user groups. Figure 2 from Study V.

Examining excess SA by diagnosis category shows that excess SA due to injury diagnoses was especially high during the first year following the accident for all road user groups and was still elevated during the following years compared to their references (Figure 11). Pedestrians and car occupants had more excess SA due to other diagnoses than bicyclists and other road users each year. They also had higher and increasing excess DP due to other diagnoses, whereas bicyclists and other road users had no such excess DP. Car occupants was the road user group with lowest excess SA due to injury diagnoses the first year, but they had the highest amount of excess SA due to other diagnoses that year.

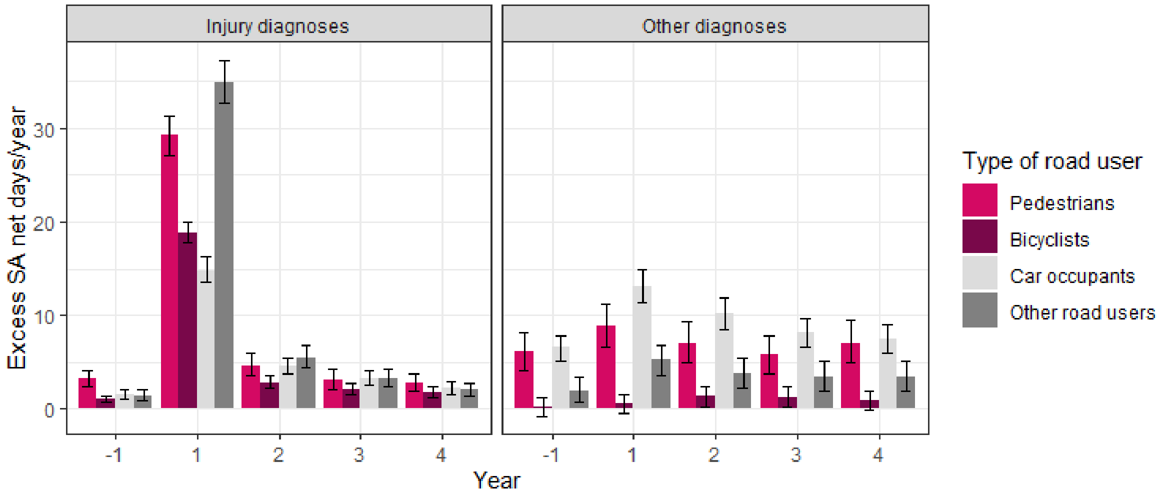


**Figure 11**. Excess sickness absence (SA) net days/year due to injury diagnoses and other diagnoses before and after the accident compared to their matched references and 95% bootstrapped confidence intervals. Figure 3 from Study V.

The highest average net SA and DP days/year were due to mental diseases and musculoskeletal diagnoses, but not for the injured individuals where SA due to injury diagnoses were higher during the first year after the accident (Figure 12).

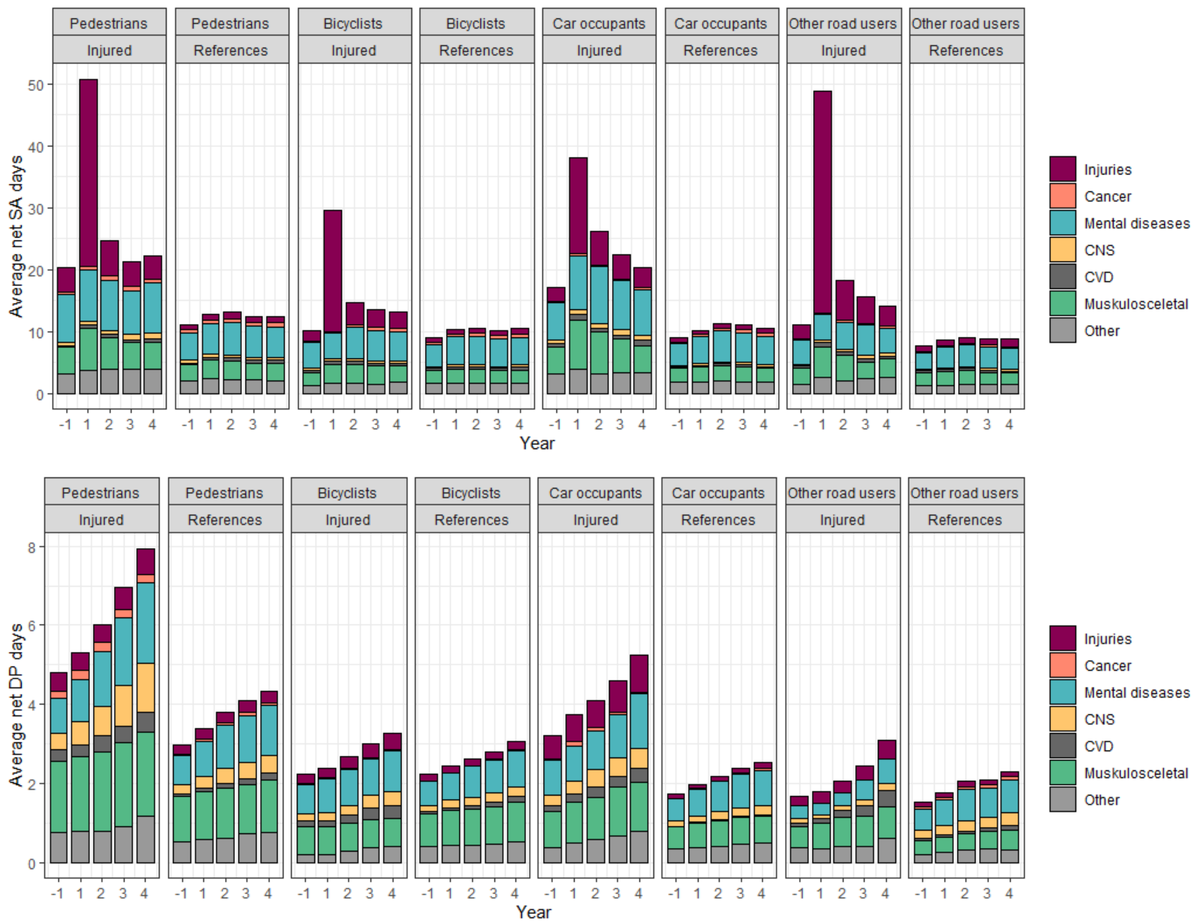


**Figure 12**. Average SA and DP net days/year due to different diagnoses before and after the accident for different road user groups and their matched references.

Abbreviations: SA: Sickness absence; DP: Disability pension; CNS: Central nervous system; CVD: Cardiovascular diseases

# 6 Discussion

The overall aim of this thesis was to generate broader and deeper knowledge of SA and DP after a road traffic accident among injured working aged bicyclists and pedestrians. This was investigated in five studies. The main findings of these studies are presented first, followed by a discussion of the results, and last some methodological considerations are discussed.

## 6.1 Main findings

The results of Study I showed that, of the bicyclists of working age who in 2010 had a bicycle crash leading to in- or specialized outpatient healthcare, 18% had a new SA spell >14 days in connection with the accident, while 10% were already on SA or on full-time DP at $T_0$. Study III observed that among the injured pedestrians the same year, 20% had a new SA in connection with the accident while 18% were already on SA or full-time DP. For both pedestrians and bicyclists, women, older individuals and individuals hospitalized at inclusion had higher OR for new SA in connection with $T_0$, as did those who sustained a fracture compared with external injuries. For bicyclists, having a TBI or a vertebral column and spinal cord injury compared to injuries to the head, face, and neck, not TBI involved higher ORs for new SA. For pedestrians, falls related to snow and ice had a higher OR for new SA compared to falls related to slipping, tripping and stumbling, overall and among women, but not among men.

Seven clusters of SA and DP sequences were identified among the bicyclists in Study II, encapsulating the heterogeneity in patterns of SA and DP in relation to a bicycle crash. The largest cluster, with 58% of the individuals, was the cluster named “No SA or DP”, showing that most of the crashes did not lead to SA >14 days. A fifth of the individuals belonged to the cluster “Immediate SA” with a new SA spell in direct connection with the bicycle crash. The cluster “Episodic SA” with a somewhat longer SA spell in connection with the crash and/or recurrent SA spells during follow-up consisted of 6% of the individuals. These two clusters were associated with high proportions of individuals with fractures and injuries to the lower extremities and to the vertebral column and spinal cord. The individuals in the cluster “Long-term SA” (2% of the individuals) had long-term SA spells lasting over major parts of the studied period. This cluster was associated with sustaining a TBI and being involved in a collision with a motor vehicle.

Among the pedestrians in Study IV, eight different clusters of SA were identified with different patterns of SA due to injury diagnoses or other diagnoses. The largest cluster was named “No SA” and consisted of 47% of the pedestrians. Compared to this cluster, all the other clusters were associated with older age, no university education, hospitalized at inclusion, and working in Health & social care. In addition, the clusters “Immediate SA”, “Episodic SA” and “Both SA due to injury and other diagnoses” were also associated with, e.g., sustaining a fracture.

In Study V, comparing the different road user groups to each other and to their matched references, there were 20,177 individuals who received in- or specialized outpatient healthcare due to a traffic-related accident. Each injured individual was matched on sex, age, education level, country of birth, and living in cities to five non-injured references (n=100,885). All road user groups had high excess SA compared to their references during the year after the accident, highest among the group other road users (40 days/year) and lowest among bicyclists (19 days/year). The following years, pedestrians and car occupants had the highest excess SA and DP (especially due to diagnoses other than injuries) compared to their references and bicyclists had the lowest.

## 6.2 Discussion of results

The research in this thesis was conducted within the area of insurance medicine research. Sickness absence and DP can be studied in several ways, using different design, data, analysis methods, etc.,[113]. A categorization of this is presented in Table 8, and the aspects relevant to this thesis are marked in bold text in the table.

**Table 8.** Categorizations of the performed studies in this thesis according to a structure for categorization of studies on sickness absence and disability pension[113]. The factors relevant for this thesis are marked in bold.

| **What is studied** | **-Design<br>-Data<br>-Analyses** | **Scientific discipline** | **Perspective taken in the research questions** | **Studied** | **Structural level of the factors included in the analyses** | **Diagnoses** |
|---|---|---|---|---|---|---|
| **Factors related to SA/DP**<br>**Factors that hinder or promote return to work**<br>"Consequences" of (being on) SA/DP<br>Sickness certification practice<br>Methods, theories | *Study design:*<br>**Cross sectional**<br>**Longitudinal**<br>Randomized controlled trial, Clinical trial, etc.<br>*Type of data:*<br>Interview<br>Questionnaire<br>**Register**<br>Medical files<br>Insurance files<br>Certificates<br>Documents<br>Video<br>Other<br>*Type of analyses:*<br>Qualitative<br>**Quantitative** | Economy<br>Law<br>Management<br>Medicine<br>Psychology<br>Sociology<br>**Public health**<br>**Epidemiology**<br>Philosophy<br>Other | **Society**<br>Insurance<br>Healthcare<br>Employer<br>Family<br>Patient | General population<br>Insured<br>In paid work (general or special jobs/organization)<br>Diagnosed Patients<br>**Injured in road traffic accident**<br>Sickness absent<br>Organizations<br>Professionals<br>Countries | National<br>Local<br>Worksite<br>Health care<br>Family<br>**Individual** | **All together**<br>Mental<br>Musculo-skeletal<br>Cancer<br>Circulatory<br>Infections<br>**Injuries**<br>Other |

How these aspects of studying SA and DP are chosen affect how the generated knowledge could be used in practice and in future research. Below follows the discussion of the results of this thesis in relation to previous research, which has sometimes studied this from different perspectives than the ones in this thesis. First some characteristics of the injured bicyclists and the injured pedestrians, followed by aspects of immediate SA in connection with the accident and lastly SA and DP in a longer perspective are discussed.

### 6.2.1 Characteristics of injured bicyclists and pedestrians

The sociodemographic and injury characteristics differed between the injured bicyclists and pedestrians in this thesis. There was a higher proportion of women, a higher proportion of older individuals and a lower proportion of individuals with university or college education among the pedestrians than among the bicyclists. The differences between them could depend on several aspects regarding which individuals walk or bicycle, to what extent they use the transportation mode, how likely they are to get involved in an accident, how likely they are to get injured if involved in an accident, and the severity of the sustained injury. For example, among pedestrians, those in older ages have previously been shown to be overrepresented[4, 59] and more likely to get a fracture when falling[60]. The use of different road transport modes and the risk of being involved in a road traffic accident were not studied in this thesis, but these aspects are important to consider when interpreting the results. For example, according to the Swedish travel survey, women walk more often and they also walk longer distances compared to men. Women and men have the equal numbers of bicycle trips, but men bicycle longer distances than women[38]. In addition, these variations highlight the advantage of matching with the references on sex and age etc., as in Study V. In this way the variation between the matched factors in the different road user groups could be accounted for.

This thesis showed that among bicyclists, upper extremities was the most commonly injured body region, followed by head, face and neck injuries. Among the pedestrians, the most commonly injured body regions were the lower and upper extremities, in particular injuries to the lower leg, ankle, foot, and other leg and wrist, hand, and other arm. This is in line with previous studies on bicyclists showing upper extremities and/or the head to be the most commonly injured body regions[39-44], and among pedestrians lower and upper extremities have been reported to be the most frequently injured body regions[4, 42, 46]. In most of the analyses among the bicyclists in this thesis, the injuries to the head were divided into the three groups: Concussion; TBI; and head, face and neck, not TBI. These injuries have different severity levels[54, 63], therefore it is a big advantage to study them separately.

Dividing upper and lower extremities into several subcategories contributes to a more complete picture of the injuries for the different road user groups and the injuries' severity in terms of SA and DP. Fractures and external injuries were the most common type of injury for both bicyclists and pedestrians, which is in line with what has been reported previously[4, 42, 46]. Setting the injured body region in relation to the type of injury is also a great advantage. In Study V, pedestrians had a higher proportion of fractures to the wrist and ankle, and as seen in Study III and Study IV most of the pedestrian injuries were from fall accidents (e.g., using their hands to catch themselves when falling or tripping in slippery shoes that could lead to such injuries). Furthermore, in study V a higher proportion of bicyclists, as in Study I and II, had injuries to the upper extremities than other body regions, while among car occupants, injuries to the head, face, and neck, not TBI, to the vertebral column and spinal cord, and to the torso were more common. Those types of injuries have also shown to be common in previous studies on car occupants[58, 94]. Moreover, other road users (which were mostly motorcyclists and mopeds) had a lower proportion of injuries to the head, face, and neck, than pedestrians, bicyclists and car occupants, in Study V. The lower proportion of head injuries could be due to the higher proportion of helmet use among motorcyclists compared to bicyclists[33]. The group other road users had a higher proportion of inpatient healthcare which could indicate higher crash severity and hence more severe injuries.

There are notably few studies on pedestrian falls (i.e., where no vehicle in motion is involved)[4, 59]. However, several studies show that pedestrian falls make up a larger proportion than pedestrians injured in collisions with motor vehicles[59, 61, 114]. This thesis found that about 71-75% of the pedestrians' injuries were due to a fall, 9% of the injuries occurred in an unspecified accident, and only 16-19% of the injuries were related to an accident with another road user involved. It is therefore noteworthy that in the current definition of road traffic accident, only accidents where a vehicle is involved are included[47], and hence the majority of the pedestrian injuries are unreported in those statistics. It is important to realize that we start all our journeys as pedestrians, regardless of the other means of transportation taken during the journey. To be able to capture the whole picture of pedestrians' injuries, with a holistic perspective of the entire journey, all pedestrian accidents need to be taken into consideration, not only those involving a vehicle in motion.

The proportion of injuries from falls due to snow and ice was lower in Study IV compared to Study III, 22% compared to 36% of all pedestrian accidents, respectively. This could partly be explained by that the winter season during 2010, when Study III was conducted, was colder and with more snowfall than during the rather mild winters in 2014-2016 when Study IV was conducted[115-117]. Colder weather in combination with snowfall led to more days with risk of injuries related to snow and ice and hence a higher proportion of such injuries. The difference in proportion of accidents related to snow and ice highlights the importance of road environment maintenance during the winter season to reduce the risk for these types of accidents, which is also called for by authors of other studies[59, 114].

#### 6.2.2 Sickness absence and disability pension

Swedish social insurance benefits cover loss of income due temporary and permanent work incapacity due to disease or injury, including workplace accidents[68]. Sickness absence is granted if a disease or injury leads to reduced work capacity and DP if a disease or injury leads to long-term or permanently reduced work capacity. Hence, it is important to both study SA in connection with the accident and SA and DP during the following years, in order to capture both the immediate and the long-term consequences of road traffic accidents. In this thesis immediate SA in connection with the accident is defined as having SA >14 days starting in connection with $T_0$ in Study I and Study III. In addition, some of the clusters in Study II and Study IV had immediate SA in connection with the accident, and in Study V, there was higher excess of SA days during the first year ($Y_{+1}$) after the accident, which may also be due to immediate SA in connection with the accident. Sickness absence and DP in a longer perspective was captured by measuring SA and/or DP during the three/four years following the accident. In addition, the diagnoses of SA were included to elucidate if the SA is due to the injury or if the SA or DP is more likely to be due to other diseases unconnected to the accident. Further, in Study V matched references were included to enable the possibility of finding out if the injured individuals had more SA and DP than those not injured.

##### *6.2.2.1 Immediate SA in connection with the accident*

Among both bicyclists and pedestrians about a fifth had a new SA spell in connection with the accident. This can be compared to the few previous studies that exist in the research field. In a Swedish study with data from 1978-79, 19% of the 447 included individuals had SA[40]. That study also included individuals younger than 16 years of age and hence not eligible for SA and older than 64 years of age in which a higher proportion have old age pension. Therefore, their results regarding the proportion of individuals with SA could have been underestimated. In another Swedish study of 791 patients (whereof 190 were bicyclists, and 46 were pedestrians) who had inpatient healthcare after a road traffic accident in 1970, 25% had SA for more than four weeks[95]. Those two studies from the 1970's had rather low numbers of patients who were admitted to specific hospitals in Sweden.

Study I and Study III showed similar results both among bicyclists and pedestrians regarding OR for New SA in connection with the accident, a higher OR for New SA among women (OR 1.4; 95% CI 1.2-1.6 and 1.7 (1.5-1.9), respectively) and higher OR with increased age. This is in line with previous research on SA in general[83], and can be seen in one previous study on bicycle crashes[39] and studies on road traffic injuries[93, 94, 96-98]. The higher levels of SA among women and older individuals injured in a road traffic accident could have several reasons, e.g., injuries such as fractures are more common among women and older individuals[118, 119]. It has further been shown that in pedestrian falls, older individuals are overrepresented[4]. Older individuals are more likely to fall and are also more likely to get a fracture when falling[60].

Both Study I and Study III showed higher OR for SA if individuals were hospitalized. This association has also been shown in previous studies[39, 43, 95], and could indicate a higher severity of the injuries that lead to inpatient healthcare. A Finnish study of 542 individuals (of which 264 were aged 15-64) injured in a bicycle crash in 1985-1986 showed longer duration of self-reported work disability days among inpatient than outpatients (82 days and 11 days, respectively)[39]. The mean and median number of net days of the new SA spells were higher among the pedestrians (Study III) than among the bicyclists (Study I), and so was the median of inpatient healthcare days among those hospitalized (3 and 1 day, respectively). In the European Union, pedestrians represent the road user group with the highest proportion of accidents where the injured are admitted to hospital and also the longest average hospital stay[46].

Fractures and internal injuries were associated with high ORs for new SA compared to external injuries for both pedestrians and bicyclists. Almost all injured body regions had higher ORs for new SA compared to injuries to head, face, and neck. For bicyclists, injuries to the vertebral column and spinal cord had the highest OR. For pedestrians, the body regions with highest OR for New SA were injuries to lower and upper extremities. This could be due to the readiness to seek healthcare being higher if your head, face, or neck is injured, while these injuries do not necessarily lead to SA (>14 days) (e.g., concussion or external facial injuries). Different injuries could lead to different work incapacity, and hence eligibility or ineligibility for SA. For example, a fracture to the lower extremities could lead to SA for someone with a job where walking and standing is needed whereas an external injury (e.g., contusions and superficial injuries) does not necessarily lead to decreased work capacity.

In a country like Sweden, winters may last for several months and thereby falls related to snow and ice were high among the pedestrians (36% and 22%, in Study III and IV, respectively). Both in Study III and Study IV the proportion of falls due to snow and ice were higher among women than among men. In addition, falls related to snow and ice had high ORs for new SA compared to falls related to slipping, tripping and stumbling, specifically among women. Snow and ice have been identified as a contributing factor to higher risk of falling[59, 61]. Days with rain followed by falling temperatures or freezing rain have been found to generate three-fold higher numbers of falls[62]. This implies that improved maintenance after snow falls is important to prevent these types of accidents and related injuries. Furthermore, future studies should investigate how the seasonal variations influence the injury patterns in more detail. It is important to prevent falls due to snow and ice, both because they are so common, and due to the high risk of SA after such an event.

Even though the results of new SA for bicyclists and pedestrians were similar, larger differences were seen for already being on SA or full-time DP at the time of the accident. Among pedestrians twice as many had ongoing SA/DP than among the bicyclists. Bicyclists and car occupants had about the same amount of ongoing SA/DP[94]. This could partly be explained by the slightly higher proportion of older individuals among the pedestrians, compared to the age distribution among the bicyclists and car occupants. Another explanation could be that if someone is on SA/DP that person might not be able to bicycle, depending on the diagnosis and the functional limitations of the person, and hence that person would be less exposed to the risk of such accidents.

#### 6.2.2.2 *Sickness absence and DP in the longer perspective*

The long-term consequences after a road traffic accident can be investigated from several different perspectives - this thesis investigated the long-term consequences in terms of SA and DP. In Study II and study IV, several clusters of patterns of SA and DP during a four-year study-period were seen, illustrating the importance of not only taking SA in direct connection with the accident into consideration, but also from a longer perspective. This has to the best of our knowledge not been previously studied among pedestrians. There are only few studies investigating long-term SA and DP in relation to bicyclist crashes and road traffic accidents[93, 95, 96, 98]. A study from Sweden reported the long-term consequences, in terms of risk of Permanent Medical Impairment (RPMI), showing that 25% of the pedestrians' falls and 20% of the pedestrians' collisions led to a permanent reduction with a RPMI of above 1%[42].

Study II confirms the association between inpatient healthcare and SA/DP, where an association between having been hospitalized and the clusters "Immediate SA", "Episodic SA", "Long-term SA", "Ongoing part-time DP", and "Ongoing full-time DP" could be seen. A Finnish study[39] found that among the hospitalized bicyclists aged 15-64 (n = 63), those injured in a collision with a motor vehicle had longer self-reported work disability than those hospitalized for collision with pedestrians, bicyclists or other road user. This may be due to greater crash severity in collisions with motor vehicles. In study II, the type of crash was not associated with the other clusters and could imply that the single-bicycle crashes are as severe as the other types of crashes, and consequently equally important to prevent. On the other hand, only those injuries that were severe enough to require in- or outpatient healthcare were included in the thesis, which could explain why no differences between types of crashes were seen.

A previous study from this project[43] investigated the duration of new SA for the different body regions among injured bicyclists. That study showed that upper extremities had the highest OR for SA 15-29 days, and for SA 30-89 days, whereas spinal injuries followed by injuries to the lower extremities and TBI had the highest OR for SA ≥ 90 days[43]. Study I showed that injuries to the vertebral column and spinal cord (37%) and TBI (36%) were the injured body regions with the highest proportions of new SA in connection with the crash. These body regions each represented only about two percent of the injuries but had a nine- and eleven-fold OR for new SA, respectively, compared with individuals with injuries to the head, face and neck, not TBI. Furthermore, Study II showed that TBI had high OR for the cluster "Long-term SA". Preventing TBI is important since the long-term SA contributes to a large proportion of SA days[70]. One possible way of effectively preventing TBI could be with the use of a helmet[63, 120].

This thesis found external injuries to be the most common type of injury among bicyclists and the second most common among pedestrians. External injuries were the most common type of injury in the clusters "No SA or DP" and "Low SA or DP" in Study II, and the clusters "No SA", "Long-term or later SA", "Other diagnoses short-term SA", "Other diagnoses long-term SA, and "DP" in Study IV, all clusters with no or little SA, or with no SA due to injury diagnoses in connection with the accident. Fractures were the most common type of injury among pedestrians and the second most common among bicyclists. Fractures were most common in the clusters represented with patterns of SA (in Study IV SA due to injury diagnoses) immediately at $T_0$. This implies that individuals with the most commonly injured body region or type of injury did not necessarily have the highest ORs for receiving new SA. Also, some of the small groups in type of injuries and injured body regions had higher OR in the clusters "Episodic SA" and "Long-term SA" and therefore contributed with more SA days, e.g., TBI as mentioned above. The contribution of SA days depends on both the number of injured and the patterns of SA and DP following the accident. In order to prevent the consequences in terms of SA and DP after a road traffic accident it is essential to take both the large numbers of injuries (e.g., fractures) leading to SA and the smaller number of injuries leading to long-term SA into consideration (e.g., TBI).

Study II and Study IV showed that about 65% had no or only short-term SA (<14 days) and DP during the follow-up. A smaller Swedish study using group-based trajectory models, found that 76% of the included 903 individuals with a road traffic injury, have a pattern of a low number of SA days during the three-year follow-up[96]. However, that study did not consider either DP during the follow-up nor the type of road traffic accident. To obtain a more complete picture of individuals with reduced work capacity due to disease or injury, both SA and DP need to be taken into consideration in order to not underestimate the total number. Moreover, SA may lead to DP and those with full-time DP are not at risk of SA.

The heterogeneity of SA and DP was highlighted in Study II and Study IV using sequence and cluster analysis where several different clusters of SA and DP patterns were identified. Some clusters were homogeneous, e.g., “No SA or DP” and “Ongoing full-time DP” in Study II and “No SA” in Study IV, whereas others were heterogeneous with several different patterns of SA and/or DP in the same cluster, e.g., “Episodic SA” and “Long-term SA” in Study II and “Long-term or later SA” in Study IV. Sequence analysis provides a more comprehensive picture of various SA and DP patterns and is a good complement to traditional regression analysis[79-82].

In study II, the heterogeneity seen in the cluster “Long-term SA” could be due to that all individuals with long-term SA spells are clustered into this cluster, not only those with SA due to injuries received in the bicycle crash, hence the SA spell could have started before or after $T_0$. Since the SA and DP diagnoses were not taken into consideration in Study II, similar arguments can be made for the other clusters. In study IV the distinction between injury and other diagnoses was included in the analysis, which facilitates understanding what SA is due to the crash and what could be due to other circumstances. The distinction between the cluster “Episodic SA” and “Both SA due to injury diagnoses and other diagnoses” was not possible without identifying the diagnoses of the SA. The pedestrians in the cluster “Episodic SA” had a SA spell due to injury diagnosis in connection with the accident and also at least one more subsequent SA spell due to an injury diagnosis, while the pedestrians in the cluster “Both SA due to injury diagnoses and other diagnoses” first had SA due to an injury diagnosis at the time of the accident and then had later SA due to other diagnoses. The later spell could be in relation to late effects of the accident (e.g., injuries, musculoskeletal disease, pneumonia, thrombosis or PTSD) but also a new accident (leading to injury) or another health issue not related to the accident. The SA spell that occurred later during follow-up does not necessarily need to be connected to the accident, especially for the latter cluster. In addition, an injury from a road traffic accident could worsen the situation for the individuals with an already ongoing SA or DP, and for this reason prolong their SA or DP.

To further shed light on whether the SA and DP received during the years following the accident is related to the accident or to another health issue, in Study V all injured individuals had matched references without an injury from a road traffic accident. In this way, the uninjured individuals' SA and DP could be compared to the individuals with an injury, and, as the references were matched on several sociodemographic factors, the differences among the road user groups were taken into consideration. Study V included not only pedestrians and bicyclists, but also other road users, in order to get a more complete picture of SA and DP following a road traffic accident.

A study from Australia on work absence (compensated days off work) following a road traffic accident found lower risks for prolonged work absence among bicyclists and motorcyclists compared to car occupants[98]. A study from France on 581 individuals injured in a road traffic accident showed that a higher proportion among late return to work were motorcyclists and a higher proportion among earlier return to work were bicyclists, however, those finding were not significant[101]. In Study V, bicyclists had fewer SA days/years than pedestrians, car occupants, and other road users, during all five studied years.

Sickness absence and DP were observed among some individuals during the one-year observation period before the accident. Among bicyclists, this was seen in the clusters “Episodic SA” and “Long-term SA”, and it was also seen among the pedestrians in several of the clusters. Study IV showed that most of the SA before $T_0$ were due to other diagnoses. In addition, previous SA and DP associated with SA and DP after the accident has also been seen in two previous studies on road traffic accidents[94, 96]. Study V showed that those road user groups (pedestrians and car occupants) with more excess SA the year before the accident also had more excess SA during the four years following the accident. Bicyclists had hardly any excess SA due to other diagnoses or excess DP before or during the second to fourth years after the crash. Bicyclists had also the lowest excess SA days during the first year following the crash. This illustrates the importance of taking both previous and ongoing SA and DP into consideration in order to not under- or overestimate the effect of the accident on SA.

It has previously been shown that disability is a risk factor for pedestrian collisions[100]. This could be strengthened in Study V showing that pedestrians had higher comorbidity the year before the accident than their matched references. This was also seen in all the other road user groups and could indicate that disability is a risk factor for injuries not only for pedestrians but also for all the other road user groups. Hence, those injured had a higher burden of disease and comorbidity from before the injury than those not injured. Furthermore, as just mentioned, the injured individuals had excess SA due to other diagnoses before the accident, especially pedestrians and car occupants. Their excess SA and DP during the follow-up could be due to the prior comorbidity, rather than the injury itself. This may prolong rehabilitation after an injury and could be one of the reasons why especially pedestrians and car occupants had more excess SA and DP throughout the entire follow-up than bicyclists and other road users. As pedestrians and car occupants had higher excess SA and DP during the follow-up their safety has to be improved, both for preventing the accident and to reduce the negative outcome from the accidents.

It is worth noting that bicyclists were the road user group with the lowest excess SA the year after the crash and very little excess SA and no excess DP during the follow-up and they also had the lowest proportion of comorbidity. This could indicate better health among the bicyclists than among the other road user groups and among the bicyclists’ references. Previous research has shown that bicyclists are in better health than those who do not cycle (physically, mentally and quality of life) and thus have a better starting point to handle the potential health issues that a road traffic accident could lead to[121]. Further, increased bicycling is good for public health both for the individual with increased physical movement, and for society: if more individuals cycle instead of driving a car, it could lead to less air pollution and hence improve the health both for the individuals bicycling and in the general population in the road environment[9, 37, 122, 123].

In study IV, the relationship between work-related factors and SA after a pedestrian accident was investigated in more detail. An Australian study found that individuals working as plant and machine operators and drivers had a longer duration of work disability (compensated days off work) after a road traffic accident[93]. In our study, working in Health & social care was associated with all clusters of SA sequences compared to the cluster "No SA". This suggests an association between this occupational sector and SA following an injury as a pedestrian. It has previously been showed that the proportions of SA and DP are higher among individuals working in health and social care[75, 124]. In addition, working in Construction was associated with the clusters "Immediate SA" and "Episodic SA" and working in Education was associated with the clusters "Both SA due to injury and other diagnoses" and "Other diagnoses long-term". This may be explained by the various demands and differences in workload that the different occupational sectors may have. Individuals in some occupations are more likely to have reduced work capacity in relation to an injury, e.g., due to work requirements of requiring mobility and/or being physically active to complete work tasks. Accordingly, sustaining a fracture to the lower extremities in an occupation that requires walking and standing could more often lead to SA. It would be beneficial to pay attention to the physical workload of different jobs in interventions to reduce SA and DP following a road traffic accident. Further studies are also needed to investigate different jobs, physical workload, and other work demands in more detail.

In Study IV, the proportion of missing information on occupation was higher in the three clusters "No SA", "Other diagnoses Long-term SA", and "DP". The proportion of individuals in each occupational sector in this study corresponds well to those of the general population in Sweden[125], with the exception of women working in Health & social care, where a higher proportion was observed among the injured pedestrians than in the general population.

## 6.3 Discussion of methods

The main strength of the studies in this thesis was the use of data from population-based high-quality nationwide administrative registers[30, 31]. This enabled the use of large study populations and allowed for subgroup analyses. In addition, the rich data made it possible to use comprehensive statistical methods such as sequence analysis. Moreover, data on SA and DP both before and after the accident were utilized.

The large number of observations implies higher precision of the estimates. However, this does not eliminate the risk of bias such as systematic errors due to omitted variables or missing information. A low degree of bias in a study corresponds to high internal validity, whereas the possibility of applying the study to other settings, i.e., the generalizability of the study is referred to as external validity. The selection bias, information bias, confounding and external validity of the performed studies are discussed below in more detail.

### 6.3.1 Selection bias

Selection bias occurs when the selection of the sample does not properly represent the population. The population in all studies were based on those with in- or specialized outpatient healthcare due to an injury sustained in a road traffic accident, those only seeking primary healthcare or who did not seek healthcare after their accident were not considered, i.e., only those accidents that were severe enough to require in- or specialized outpatient healthcare were included in the study group. This may underestimate the number of accidents, especially those resulting in minor injuries. In addition, in

Sweden, individuals more often seek healthcare if in need of it as all individuals are covered by the general and public healthcare insurance. This means that there are small (but not insubstantial) costs for the individual at the point of use. Moreover, the access of healthcare could vary with, e.g., distance to hospitals or possibilities for transport to them, which could lead to instead seeking care at primary healthcare or to not doing it at all if not deemed very serious.

All studies in this thesis used data from high-quality nationwide registers[30, 31] covering the whole population of all residents of working age in Sweden. This will minimize the selection bias, since all individuals are included. Also, all individuals of working age in Sweden are covered by the public SA and disability benefit insurance scheme. Therefore, there is a lower a risk of adverse selection where those with the greatest need have higher coverage rate of sickness insurance than others, or, conversely, of those with a higher risk being less likely to be granted insurance or having to pay higher premiums for their insurance. However, self-employed individuals have varying numbers of unreimbursed qualifying days before receiving benefit from the SIA. This could lead to underestimation of SA and DP for those individuals, and to a risk of adverse selection for specifically self-employed individuals.

Previous studies have mainly been based on small samples from emergency units or police data[27, 39, 40, 95]. In Sweden, as well as in other countries, the number of accidents is often underestimated in police reports[26, 27]. Hence, the use of healthcare data is a strength when studying injuries sustained in road traffic accidents[27, 30, 31]. In addition, for pedestrians, all pedestrian injuries are included with the use of healthcare registers, not only those seeking care at an emergency unit. Several recent studies stress that pedestrian injuries should be included in the international definition of traffic accidents[4, 42, 47]. This thesis further strengthens this argument as 71-75% of the pedestrian accidents were due to falls in the road environment with no other road user involved.

### 6.3.2 Information bias

Information bias occurs when the variables (exposure and/or outcome) are misclassified, e.g., through measurements error in the information required. Non-random misclassification may lead to under- or overestimation of the estimates and the results may be biased, whereas random misclassification may lead to dilution of the estimates. The use of register data with good validity reduces the risk of misclassification and enabled several years of complete follow-up data. Furthermore, the rich data used in the sequence analysis in Study II and Study IV allowed for a more complete picture of the heterogeneous SA and DP patterns where several weeks of data were used based on dates on both SA, DP, and in- and specialized outpatient healthcare, rather than classifying individuals based on a single point in time.

However, when using register data, information on some relevant variables may be missing or unknown for all or for a subset of the individuals. This latter is the case for type of accident which was coded as unspecified for about a fifth of the bicycle crashes and about a tenth of the pedestrian accidents. In Study I and Study II those crashes were grouped as single-bicycle crashes as the presumed majority of those were single-bicycle crashes, e.g., those where another bicycle or a vehicle were involved are presumed to more likely be coded as such since there are more individuals involved in these types of accident. In Study III and Study IV, 8% and 10% respectively were unspecified pedestrian accidents and those were categorized in a separate group in the variable type of accident.

In study IV, the proportion of missing information was high in the variables occupational sector, private/public, and type of occupation, especially for the individuals in the clusters “No SA”, “Other diagnoses long-term SA”, and “DP”. This could indicate that the individuals in the cluster “No SA” were less likely to have a job and hence are not eligible to SA benefits (since they have no income from work, unemployment or parental leave). The individuals in this cluster were also slightly younger than in the other clusters (which means that they might still be studying or had not yet begun their first job). The high proportion of missing in the other two clusters could be due to the high proportion of these individuals that were already on long-term SA and DP the year before the accident, when the information on occupation was assessed. In study V, those not in paid work were excluded to reduce the uncertainty whether an individual is eligible for SA and DP or not, and hence in risk of SA and DP.

Furthermore, the exact date of the accident is not available in hospital data, only the date of in- or specialized outpatient healthcare due to the injuries sustained. Even though the majority of the individuals are likely to seek healthcare immediately, especially for the more severe injuries, an individual might come to specialized healthcare one or some days after the accident. This delay might be due to not being close to healthcare, due to initially not feeling the need for healthcare, or due to having been to primary healthcare first. To handle the uncertainty regarding the exact accident date, and the fact that some individuals started their SA some days before or after their healthcare visit/hospitalization (e.g., because they did not seek specialized healthcare until a couple of days after the accident - or they might have waited to report the SA spell, e.g., due to the accident happening during a weekend or holiday), new SA in connection with the accident was in Study I and Study III defined as SA spells starting any day between 4 days before and 4 days after the first healthcare visit/hospitalization ($T_0$). This was decided based on the distribution of the start dates of SA spells, as a substantially higher proportion of new SA spells was seen during this time-window. Similarly, in Study II and Study IV, weekly data was used, and the week of the accident ($W_0$) was defined as the date of the healthcare visit/hospitalization and three days before and three days after that date ($T_0$). In Study V, this was not taken into consideration and could hence lead to an overestimation of SA and DP net days the year before the accident. A wash-out period, excluding those with previous visits/hospitalizations due to traffic accidents, was used in order to only include individuals with new accidents (i.e., not individuals revisiting the healthcare after some time).

The variables type of injury and injured body region were categorized using diagnoses from NPR with high coverage of the diagnoses. For inpatient healthcare 99% and for specialized outpatient healthcare, 98% of the visits have diagnoses[106]. The majority (78%) only had one injury diagnosis registered on the date of the accident. For those who had more than one, a selection of only one injury diagnosis was made, which might have led to information bias through, e.g., over- or under-estimation of different injury diagnoses. Furthermore, the variables type of injury and injured body region had about 2% with “other or unspecified” diagnoses. While this may have also resulted in an under- or overestimation of some diagnoses, since they were so few, it is likely that this did not influence the results regarding diagnoses in any major way.

Only information on SA spells >14 days was available. The use of this register-based information can be viewed as both a limitation and a strength. It can be seen as a strength as all SA is verified by a physician, this will reduce the misclassification compared to, e.g., self-reported SA, and hence limit information bias. On the other hand, it can also be seen as a limitation, as there is no information on SA spell <14 days for most individuals, and most SA spells are short-term. In Sweden, about three quarters of all SA spells are shorter than 7 days, and only about 2% are longer than 90 days. However, spells longer than 90 days contribute to about half of all SA days in total[70, 71].

### 6.3.3 Confounding

A confounding factor is associated with both exposure and the outcome but is not a step in the causal pathway between the exposure and the outcome, hence, not controlling for a confounder might under- or overestimate the true effect. The use of microdata from several nationwide registers and with large study-populations, made sub-group analyses possible, with more clusters and categorizations, and it was also possible to include several potential confounders in the analyses. The results in the thesis were controlled for sociodemographic factors (sex, age, level of education, country of birth, type of living area, and marital status), work-related factors (occupational sector, private/public, and type of occupation), type of specialized healthcare (inpatient or specialized outpatient), and accident related factors (type of accident/crash, type of injury, and injured body region). However, there might be residual confounding for unmeasured factors. Information regarding the accident is not included in NPR and could not be studied. Examples of such factors are, e.g., infrastructure, traffic environment (e.g., pathway, roads, intersections), road surface (e.g., wet, gravel, potholes), if a helmet was used, type of shoes worn (e.g., ice spikes), time of the day, lightning conditions etc.

### 6.3.4 External validity

External validity refers to the generalizability of the findings from one study to another population, e.g., a more specified target population, the general population, or other countries. All studies were based on the population of Sweden of working age, receiving in- or specialized outpatient healthcare due to injuries sustained in a road traffic accident. Thus, the results are directly applicable to the general population of working age in Sweden and probably to other countries (e.g., Nordic countries) with extensive welfare systems. However, to generalize to other countries, aspects of the social and health insurance system, labour market participation etc. need to be considered. In addition, the road environment for pedestrians and bicyclists varies between countries, e.g., low- and high-income countries[45].

# 7 Conclusions

The proportions of individuals starting a new SA in connection with the accident were almost the same among bicyclists and pedestrians, and was associated with sustaining a fracture, among others. However, pedestrians had more ongoing SA and DP before the accident and more excess SA and DP after the accident than the bicyclists.

*Study I:* Among injured bicyclists, the OR for new SA were higher among women, and older individuals, as well as among individuals with a fracture, injured in a collision with a motor vehicle, TBI, injuries to the vertebral column and spinal cord, and injuries to the upper and lower extremities.

*Study II:* Among injured bicyclists seven clusters of SA patterns for four years were identified. There were two clusters with no or little SA, three with different levels of SA and two with different extents of DP. Fractures were more frequent in the clusters with immediate and episodic SA and TBI and collision with motor vehicle was more frequent in the cluster with long-term SA.

*Study III:* Among injured pedestrians, the OR for new SA were higher among women, older individuals, individuals with a fracture, internal injuries, injuries to the lower leg, ankle, and foot, injuries to the wrist and hand, and injured in a collision with a motor vehicle. Moreover, women had high ORs for new SA after a fall related to snow and ice.

*Study IV:* Among injured pedestrians eight clusters of SA patterns for four years were identified. Almost half of the pedestrians had no SA: compared to those, all other clusters were associated with older age, hospitalized at inclusion, and working in health and social care. The three clusters with SA due to an injury diagnosis in direct connection with the accident were associated with women, fractures, and injuries to the lower and upper extremities.

*Study V:* All road user groups had excess SA due to injury diagnoses the first year after the accident compared to their non-injured references. Pedestrians and car occupants had more excess SA due to other diagnoses and more excess DP throughout the study period, while bicyclists had no such excess SA or DP compared to their references.

# 8 Future Research

The research on SA and DP among injured bicyclists and pedestrians is very scarce, further research is needed in order to get a more comprehensive as well as deepened understanding of the SA/DP-situation among individuals injured as bicyclists and pedestrians. Some aspects that need to be taken into consideration in future research are listed below.

- Include information on already ongoing SA and DP at the time of the accident, and preferably also on previous SA and DP.
- Include information on SA and DP diagnoses to get a better understanding of the SA and DP and possibly to what extent the SA and DP are related to the accident or due to other causes.
- Include additional information about the accident in the analyses, e.g., the road environment such as light condition, state of the road, and type of road, and protective gear like helmet and type of shoes.
- The impact of previous healthcare/comorbidity and use of medications need to be further evaluated.
- Also including the individuals who had primary healthcare in connection with the accident to capture the impact of minor injuries could give a better understanding of the problem.
- Compare data from different years in order to find trends or effect of different injury prevention interventions and other changes, e.g., rule changes in the social insurance benefit system and traffic safety improvements.
- Investigate in more detail how the seasonal variations influence the injury patterns (e.g., regarding improved maintenance after snowfalls).
- The relationship between work-related factors (e.g., physical workload and other work demands) and SA after an accident need to be investigated in more detail.

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