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TSR TRAFFIC SAFETY RESEARCH
AN INTERDISCIPLINARY JOURNAL

Research article

Rollator related pedestrian single accidents and collision events in Sweden

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Abstract: Rollators (four-wheel walkers in USA; zimmer frames in UK) are commonly used as mobility aids for the elderly and people with a variety of disabilities. Pedestrian rollator users are a sub-group of Vulnerable Road Users (VRUs), although this group is rarely recognised in traffic safety contexts. The aim of this study is to extract and analyse rollator related pedestrian accident and injury data in Sweden. The results will provide valuable insight into the risks and obstacles rollator users are exposed to in the traffic environment and may in the long term contribute to improving the mobility of this group. The current study is based on data from 2,020 accidents involving 2,305 persons extracted from the Swedish Traffic Accident Data Acquisition (STRADA) database. For consistency reasons, a subset of data (N = 745) was analysed in order to investigate the development of accidents over a period of 10 years. Thereafter, each accident in the whole data set was registered as either single or collision. The results show that the number of rollator accidents in Sweden increased by approximately 80% during 2007–2016. Females dominate the injury statistics of single accidents, collisions, as well as fatal outcome, which may be due to exposure and/or differences in physical characteristics. Single accidents are much more common than collisions (n=1,668 and n=352, respectively) and the injury consequences are at least as serious. Data from the present study have revealed that the frequency of minor injuries (ISS 1–3) is 4.3 times, moderate (ISS 4–8) 6.0 times and serious injuries (ISS 9–15) 8.9 times higher in single accidents than in collisions. Fatal injuries are, however, more common in collision events (33 in comparison to 8). The vast majority of single accidents (99%) was due to falls. Many of the single accidents (29%) were caused by ground level differences (typically a curb) or due to surface conditions (19%). Collisions involved cars, trucks or buses in 91% of cases, occurring predominantly in car parks (31%) and on (zebra) crossings (30%). In 54% of cases the vehicles reversed into the rollator. Abbreviated Injury Scale (AIS) 3+ injuries were dominated by head (36%) and torso (33%) injuries in collision events, and hip fractures (71%) in single accidents. The present study shows that further research into rollator user related accidents, both single accidents and collision events, is required. In order to introduce appropriate measures, future work should follow up on accident and injury developments and further improve the quality of mobility aid related accident data in general. Improved stability and design, proper training programmes, effective maintenance services, development of a supporting infrastructure would contribute to increased safety for rollator users.

Keywords: acute injuries, elderly, rollators, traffic environment, vulnerable road users (VRUs), four-wheeled walkers

1 Introduction

"*Road safety is a challenge of epidemic proportions. With 1.25 million people killed on the world's roads each year and another 20–50 million seriously injured, road traffic injuries have become a public health priority whose social and economic implications extend well beyond the transport sector*" (*World Bank, 2017*, page 6). The European Commission reported that 25,500 individuals died on European Union roads during 2016 and estimates that 135,000 suffered serious injuries (*European Commission*, Fact Sheet 2017). During 2019 in Sweden, out of a population of 10 million, 221 individuals were fatally injured and 3,850 seriously injured in accidents involving at least one 'moving vehicle' in the traffic environment (*Swedish Transport Administration, 2020*). Since 1997, traffic safety measures in Sweden have been based on what is commonly referred to as the Vision Zero charter, which has successfully contributed towards reducing the number of occupant fatalities in vehicles (*The Government of Sweden, 1997; Johansson, 2009; Belin et al., 2012*). A similar approach, frequently referred to as Sustainable Safety (*SWOV, 2018*) or the Safe System Approach (*International Transport Forum, 2008*), has been adopted by several other countries.

Vulnerable Road Users (VRUs) are defined in the Intelligent Transport Systems (ITS) Directive (*2010*, page 4) as "*non-motorised road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation*". According to the European Commission, VRU transport accounts for the same proportion of road fatalities as cars (46%) (*European Commission*, Fact Sheet 2017). VRUs, such as pedestrians, cyclists and moped riders, for whom efforts in enhancing traffic safety is still facing major challenges, have steadily been attracting more attention (*WHO, 2009 & 2018; Swedish Transport Administration 2017 & 2018*).

Pedestrians is a multifaceted sub-group of VRUs, involving all people in society ranging from children to the most fragile elderly. Traditionally, traffic safety has focused on avoiding or mitigating collision between pedestrians and other ´moving vehicles´ (*Elvik et al., 2009*). However, pedestrian single accidents occurring in the traffic environment, of which the majority comprises fall accidents, is an immense and overlooked problem (*Aldman et al., 1976; Nilsson, 1986; Öberg et al., 1996; Öberg, 2011; Berntman, 2015; Tournier et al., 2016; Methorst et al., 2017; Schepers, 2017; Aldred, 2018; Elvik & Bjørnskau, 2019; Amin et al. 2022*). This may partly be explained by the fact that since no vehicle is involved, pedestrian single accidents have not (yet) been included in the official definition of a road traffic accident (*Swedish Transport Administration, 2020*). However, earlier publications have argued that pedestrian single accidents should be included in the international definition of traffic accidents (*Berg et al., 2016; Methorst et al., 2017*).

In Sweden, pedestrian single accidents originating from the traffic environment (*Swedish Transport Administration, 2020*), averagely represent 45% of serious injuries (PMI 1%+) and 34% of very serious injuries (PMI 10%+, as defined by *Malm et al., 2008*). Thus, pedestrian single accidents represent the sole largest cause of injury in the traffic environment in Sweden. These single pedestrian accidents, mainly falls, can lead to disability, loss of independence, and fear of falling (*Cruz et al., 2019*). Age (elderly) and gender (females) are two important parameters affecting both risk of injury, as well as type and severity of the injury (*Öberg, 2011*). *Öberg (2011)* found that twice as many females than males were injured in single pedestrian

accidents, which could not be explained by exposure data; the greatest difference was found in the age group ≥50 years. Traffic safety strategies must consider that the growing elderly population (*European Commission, 2018*), whose physical condition is inherently different to that of younger adults (*Aldred, 2018; Musselwhite, 2021*), will in future need to use the traffic system to a greater extent.

Walking aids, such as rollators (four-wheel walkers, USA; zimmer frames, UK; see Figure A1 in Appendix), are commonly used by elderly pedestrians in the traffic environment. The rollator is a Swedish innovation developed as a training tool by the hospital social worker, Aina Wifalk, who did not patent her innovation because she wanted the rollator to be available to everyone (*Råssjö, 2016*). Since its introduction in 1981, when the first rollator was introduced on the market, it has been widely accepted. In Sweden, 40% of women and 20% of men use some form of walking aid at the age of 75; at 85 years the proportion increases to 70% and 55%, respectively (*The Swedish Handicap Institute, 2014*). However, knowledge and awareness concerning acute rollator related accidents and injuries in the traffic environment are limited. Hence, the aims of this study were to analyse national rollator related accident and injury data reported to the Swedish Traffic Accident Data Acquisition (STRADA) database, in particular the development over a period of 10 years, and investigate crash circumstances as well as risk factors (by comparing with data for the general population, where applicable). The results will provide valuable insight into the risks and obstacles that rollator users are exposed to in the traffic environment and may also contribute to improving the mobility of this group in the long term. This knowledge may also contribute to Sweden achieving the goal of reducing the number of seriously injured road users by 25%, including pedestrian single accidents, by 2030 (*The Government of Sweden, 2020*). This study relates to our previous study into powered mobility devices (*Carlsson & Lundälv, 2019*).

2 Methodology

2.1 Data collection – STRADA

Relevant data from accidents/injuries involving rollator users were extracted from the Swedish Traffic Accident Data Acquisition (STRADA) database. The national information system, STRADA, contains data provided by the police and the national health service of traffic accidents and injuries sustained within the Swedish road transport system. To ensure data is comprehensive and as detailed as possible, any data entered in STRADA is derived from two separate sources: police reported traffic accident records and records provided by medical establishments/health care providers.

Including hospital records in the study enhances the understanding of the type, as well as the severity of injuries sustained. Furthermore, hospital data reduces the amount of unaccounted accidents and increases police insight into certain categories of road traffic accidents (in particular accidents involving VRUs such as pedestrians, cyclists and moped riders). Police records generally incorporate information not included in hospital reports, for instance, the exact circumstances and the environment in which a traffic accident occurred.

STRADA is administered by the Swedish Transport Agency. Early trials of the database were initiated in 1999, and reports have been received regularly by the police nationwide since 2003. In 2003, STRADA obtained data from 29 hospitals, this figure has gradually increased to 68 hospitals in 2012 and 71 hospitals in 2016.

Since the STRADA database lacks specific variables regarding walking aids, what is generally referred to as a 'free text search' was performed, in order to identify relevant cases. The keywords used for this search were 'rollator' plus synonyms. The search resulted in a total of 2,361 unique accident identities, i.e., respective accidents, involving 2,688 persons during the period 1 January 2000 to 31 May 2017.

2.2 Data analysis

Information from the 2,361 accident cases and 2,688 persons were systematically analysed using Excel in the four phases described below (Figure 1). The statistical study was limited to a simple descriptive analysis.

- The first phase involved removing data concerning 354 accidents/383 persons from the dataset, considered irrelevant for the scope of this study. Consequently, the current study is based on data from 2,020 accidents and 2,305 persons.
- The second phase involved performing a development analysis to investigate whether the annual number of accidents involving rollators is increasing, decreasing, or at a static level. Sweden is divided into 21 different hospital regions; each region began reporting to STRADA at different times between 2000 to 2016 (Figure 2). For consistency reasons, inclusion criteria for the development analysis stipulates that a hospital region must have been fully reporting to STRADA during the 10-year period 2007–2016, which qualified 10 hospital regions and 745 accidents.

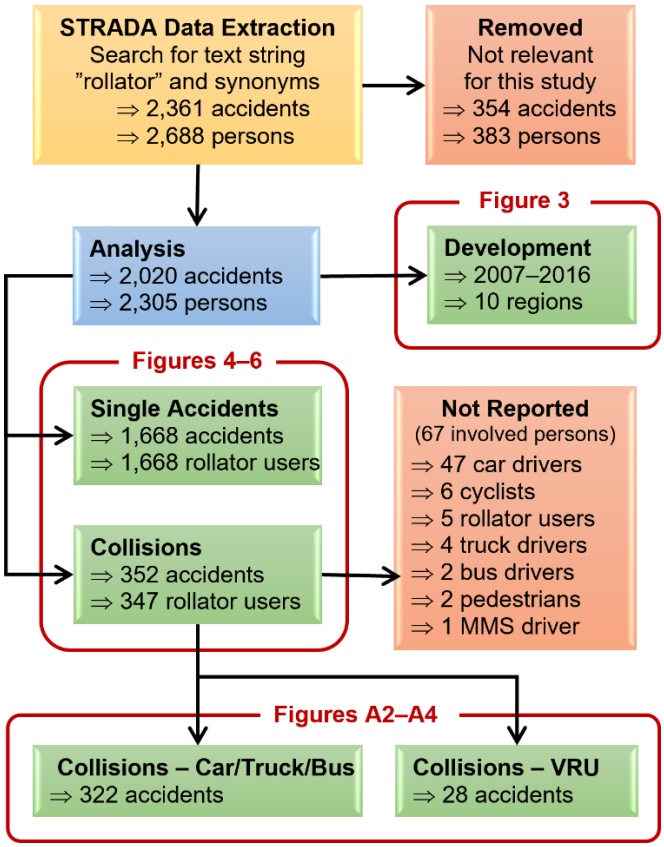

Figure 1. Schematic overview of performed data analysis

- The third phase involved registering each accident as either 'single' (n=1,668) or 'collision' (n=352), and categorising them based on text analysis of available information, in particular the accident description:

  Single accidents were categorised as *Fall* (the rollator user impacted the ground) or *Miscellaneous* (sprained ancle, slipped and hit the rollator—Table 1). The circumstance of a single accident event was categorised as *Curb*, *Trip*, *Stuck*, i.e., the rollator got stuck, *Surface*, i.e., unevenness, poor maintenance, etc, *Rolling away*, i.e., the user was unable to keep up the speed with the rollator, *Miscellaneous*, and *Unknown* (Table 1). Examples of circumstances incorporated in the Miscellaneous category include 'knocked over by the

wind', 'lost balance', 'pulled over by the dog', 'distraction', 'down-hill slope', 'heavily loaded rollator', and even 'aquaplaning' (in one case).

Collision events were categorised as *Truck/Bus*, *Car*, *MC/Moped/MMS* (MC = Motorcycle; MMS = Motorised Mobility Scooter), *Bicycle*, *Pedestrian* or *Miscellaneous* (tourist train) (Table 1). The circumstance of an event was categorised as *Zebra Crossing*, *Crossing*, *Road Section*, *Car park*, *F/C Lane* (combined footpath and cycle lane), *Footpath* (including pavement), *Entrance*, or *Miscellaneous* (Table 1). Examples of circumstances incorporated in the *Miscellaneous* category included 'bus stop', 'railway station', 'square", 'petrol station', and 'amusement park'.

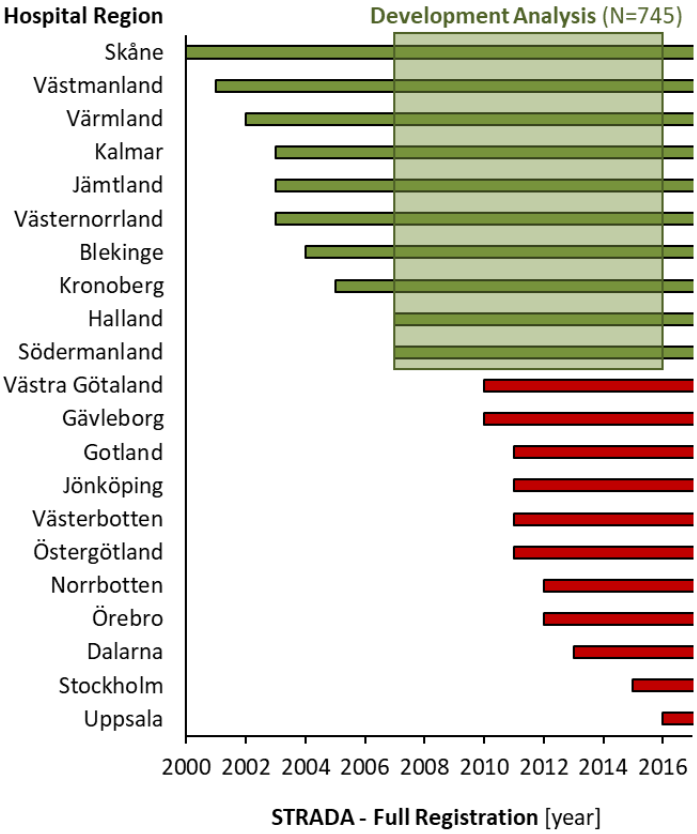

Figure 2. Hospital regions in Sweden including year they began reporting to STRADA. Green bars indicate that the region was used for the development analysis in the present study, covering the years 2007–2016. Red bars indicate that the region was excluded from the development analysis, since reporting to STRADA began after 2007.

Both single accidents and collisions, injured body region, injury severity and other relevant parameters were categorised in accordance with Table 1. The Injury Severity Score (ISS) is defined as the sum of squares of the highest Abbreviated Injury Scale (AIS) score in each of the three most severely injured body regions, with one exception; the ISS score which is automatically computed as 75 for individuals sustaining an injury of AIS 6 severity (the maximum ISS possible) (*MacKenzie, 1984; Stevenson et al., 2001*). The injury severity was categorised as *Uninjured*, *Minor* (ISS 1–3), *Moderate* (ISS 4–8), *Severe* (ISS 9–), *Fatal* and *Unknown*, in accordance with the STRADA registry.

- The fourth phase included categorising collision events into *VRU collisions* (n=28), and collision with *cars/trucks/buses* (n=322).

Table 1. Classification of accidents involving rollator users

	Single	Collision
Event	• *Fall* • *Miscellaneous*	• *Truck/bus* • *Car* • *MC/moped/MMS*[1)] • *Bicycle* • *Pedestrian* • *Miscellaneous*
Circumstance	• *Curb* • *Trip* • *Stuck* • *Surface* • *Rolling away* • *Miscellaneous* • *Unknown*	• *Zebra crossing* • *Crossing* • *Road section* • *Car park* • *F/C lane*[2)] • *Footpath* • *Entrance* • *Miscellaneous*
	Single & Collision	
Body Region	• *Head* • *Arm* • *Leg* • *Hip* • *Torso (excl. hips)* • *Unknown*	
Injury Severity	• *Uninjured* • *Minor injury (ISS 1–3)*[3)] • *Moderate injury (ISS 4–8)*[3)] • *Severe injury (ISS 9–)*[3)] • *Fatal injury* • *Unknown*	
Others	• *Season* • *Day* • *Time* • *Age* • *Sex*	

[1)] *Motorcycle (MC); Motorised Mobility Scooter (MMS)*

[2)] *Combined footpath and cycle lane (F/C lane)*

[3)] *Injury Severity Score (ISS) (MacKenzie 1984; Stevenson et al. 2001)*

3 Results

3.1 10-year development

Data was extracted for the development analysis from 10 hospital regions in Sweden for the period 2007–2016, as indicated in green in Figure 2. In total, 745 accidents were included, and their distribution has been depicted in a scatter plot (Figure 3). As seen in the plot, the rollator accidents increased by approximately 80% during 2007–2016.

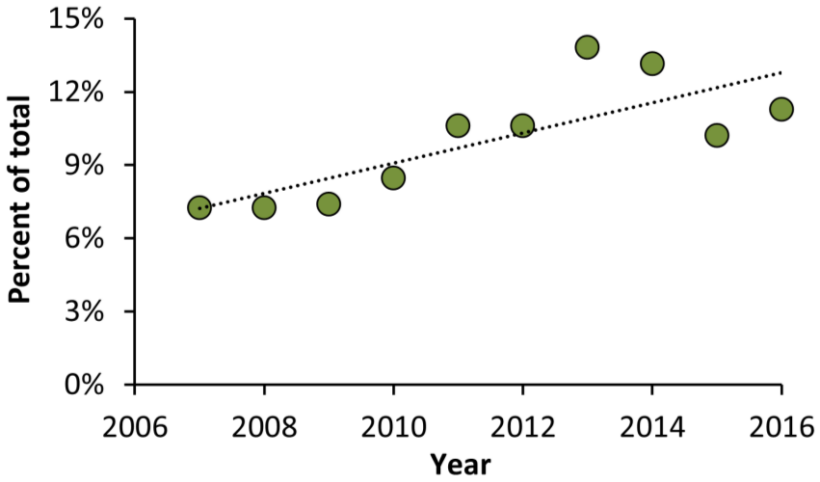

Figure 3. The number of rollator accidents increased between 2007–2016 (based on data from 10 hospital regions).

3.2 Single accidents (n=1,668)

The vast majority of single accidents (99%) was due to falls (Figure 4a). These accidents were most often caused by a difference in ground level (typically a curb) (29%), surface conditions (unevenness, poor maintenance, etc.) (19%), trip (9%), the rollator rolling away (7%) or stuck (2%) (Figure 4c).

Severe injury (ISS 9–) was registered in 18% of cases, moderate (ISS 4–8) 28%, minor (ISS 1–3) 50%, while 2% of cases remained uninjured (Figure 4e). Fatal outcome was registered in eight cases (0.5%), of which five involved females (mean age 88 years) and three involved males (mean age 85 years); in three of these cases the death was not caused by the accident. The body region most commonly injured in single accidents was the head (36%), followed by upper limb/arm (27%), hip (16%), lower limb/leg (15%), and torso (6%) (Figure 5a). AIS 2+ injuries were most frequently situated in the arm (39%), hip (33%), and head (14%) (Figure 5c). AIS 3+ injuries were dominated by hip fractures (71%) (Figure 5e).

3.3 Collisions (n=352)

The collision counterpart most often involved a car (77%), followed by truck/bus (14%), bicycle (4%), MC/moped/motorised mobility scooter (MMS) (2%) and pedestrian (2%) (Figure 4b). Fatal injury was registered in 9% of cases; severe (ISS 9–) 10%, moderate (ISS 4–8) 22%, minor (ISS 1–3) 56%, while 1% of cases remained uninjured and 2% unknown (Figure 4f). Many of the accidents (29%) occurred while crossing a road (21% zebra crossing; 8% crossing) (Figure 4d). Pedestrians, cyclists, moped, MC or MMS drivers (VRUs) (n=28) (Figure A2a in Appendix) were most often involved in rollator collisions on footpaths (39%), combined FC paths/bicycle lanes (18%), road sections (18%) or (zebra) crossings (15%) (Figure A2c in Appendix). Cars, trucks and buses (n=322) (Figure A2b in Appendix) were most frequently

involved in rollator collisions in car parks (31%), on zebra crossings (22%), crossings (8%) or road sections (20%) (Figure A2d in Appendix). In 54% of cases, the vehicle reversed into the rollator.

In VRU collisions, 61% of the rollator users had sustained minor injuries, 18% moderate and 4% severe injuries, however, a large number remained unknown (18%) (Figure A2e in Appendix). Limited information was available for the rollator users with regard to injured body region (36% unknown) (Figures A3a,c in Appendix). Leg and arm injuries accounted for 15%, respectively, followed by head (13%), hip (10%) and torso (10%) (Figure A3a in Appendix). AIS 2+ injuries were dominated by arm injuries (50%), followed by head, torso and hip (17%, respectively) (Figure A3c in Appendix).

In car/truck/bus collisions, 55% of the rollator users had sustained minor injuries, 23% moderate, 10% severe, whereas 10% represented fatal injuries (Figure A2f in Appendix). Of the 33 fatalities, 20 involved females (61%) and 13 males (39%), all were elderly (85 ±8 years old). Information regarding injured body region was missing in 22% of cases; the known cases were distributed over the head (24%), arms (13%), legs (19%), hips (7%) and torso (15%) (Figure A3b in Appendix). AIS 2+ injuries were most frequently located to the head (26%), torso (25%), and leg (23%) (Figure A3d in Appendix). AIS 3+ injuries were dominated by head (36%) and torso (33%) injuries (Figure A3e in Appendix).

Generally, the predominant reason for the missing information with regard to injury data was due to the accident only being recorded by the police, i.e., not by any hospital. In some cases, data were missing since only one of the collision partners was recorded in STRADA (see ‘not reported’ in Figure 1).

3.4 Other Parameters

Both single accidents and collision events were evenly distributed over the year (Figure 6a), however, VRU collisions were more common during the summer (Figure A4a in Appendix). Relatively few rollator collisions had occurred during weekends (especially Sundays), being more common during weekdays, whereas single accidents were more evenly distributed over the week (Figure 6b, A4b). Few rollator accidents occurred during late evenings or nights, occurring most frequently (82%) during daytime between 10 am and 6 pm, peaking (25%) between 2 pm and 4 pm (Figure 6c, A4c).

The analysis revealed that 2.4 times as many females (71%) than males (29%) were involved in rollator single accidents. In collisions, similar differences were found between female (74%) and male (25%) rollator users, however, gender was unknown in some cases (1%), probably due to the VRU counterpart being injured, i.e., not the rollator user.

The average age of the rollator user was 82 ±9 years (median 84 years) in collisions, and 81 ±10 years (median 83 years) in single accidents (Figure 6, A4d).

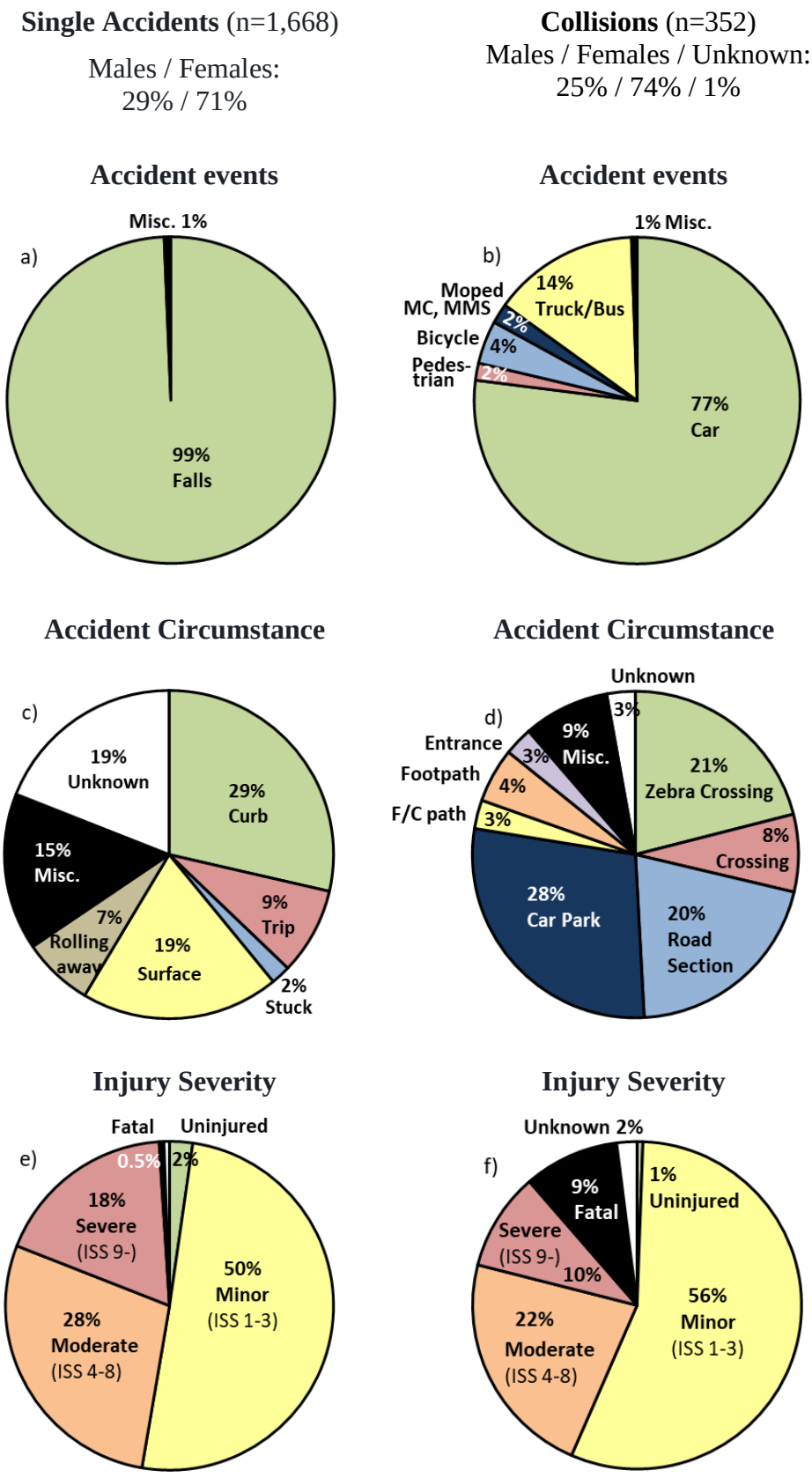

Figure 4. a) Single and b) collision accident events; c) single and d) collision accident circumstances; e) single and f) collision accidents injury severity

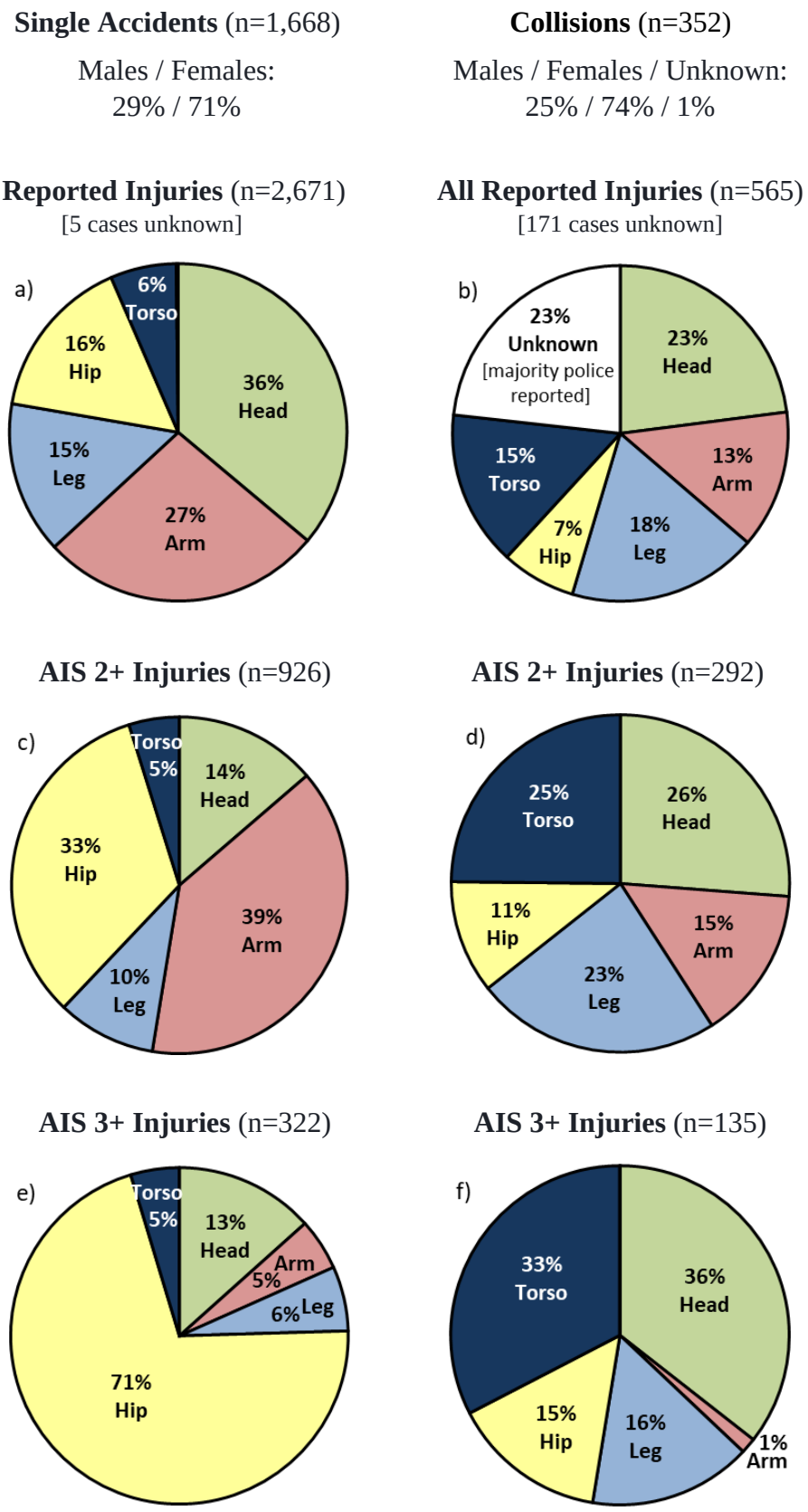

Figure 5. Injured body parts based on: all injuries in a) single and b) collision accidents; AIS 2+ injuries in c) single and d) collision accidents; AIS 3+ injuries in e) single and f) collision accidents

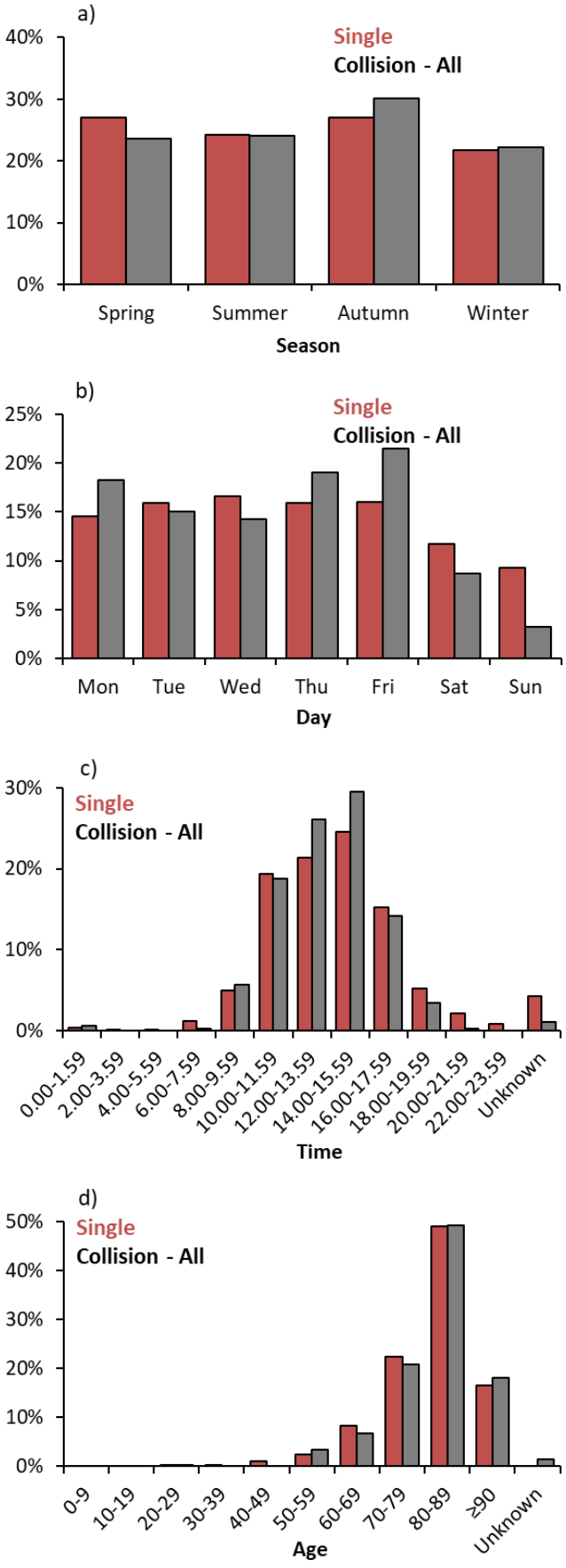

Figure 6. The distribution of a) season, b) day, c) time, and d) age of the driver in PMD single accidents (in red, n=1,668) and collisions (in grey, n=352)

4 Discussion

Research into rollator users has traditionally been focused on usage, based on the ability of disabled individuals to manoeuvre a rollator and the significance of the mobility aid for everyday quality of life. The present study provides a new perspective based on national traffic accident data (STRADA) of acute traffic related injuries involving rollator users. This is in line with the Vision Zero charter, which was adopted by Sweden already 25 years ago (*The Government of Sweden, 1997*).

The results of this study reveal an increase in the number of rollator related accidents in Sweden (Figure 3). It is likely that the rising proportion of elderly members of society will contribute to a further increase in the number of rollator users, potentially continuing the escalation in rollator related accidents.

Single accidents among pedestrians are by definition not registered as road traffic accidents, since no vehicle is involved. Thus, these accidents are more or less invisible in traffic safety contexts. However, many pedestrians are seriously injured due to single accidents in the traffic environment. A recent study from Sweden found that the majority of fall related injuries occur outdoors (56%, *Ekbrand et al., 2020*), which is in line with previous findings (*Kelsey et al., 2012; Li et al. 2006, 2014*). Data from the present study revealed that minor injuries (ISS 1–3) occur 4.3 times more often, moderate (ISS 4–8) 6.0 times and serious (ISS 9–15) 8.9 times more often, in single accidents than in collisions. Fatal injuries were however more common in collisions than in single accidents (33 and 8, respectively, by definition within 30 days from the injury event, Figure 4ef). Yet, hip fracture was the most dominant AIS 3+ injury among rollator users in single accidents (71%, Figure 5e), somewhat higher than for pedestrians in general (68% in Sweden, *Carlsson & Svensson, 2015*). In Sweden, 15% of women and 20% of men die within four months after a hip fracture (*Rikshöft, 2020*). Thus, after four months from the injury event the number of fatalities related to single accidents may exceed those related to collisions. For the vast majority, walking is one (of several) means of transport, i.e., a chain of events, utilised to travel from one place to another, whereby each type of transport is associated with a certain accident risk (*Aldman et al., 1976*). From the "whole-journey" perspective, a bus trip may not be that safe if pedestrian single accidents en route to the bus stop would be accounted for (*Aldman et al., 1976; Berntman et al., 2012*). Thus, pedestrian single accidents should be included in the road traffic accident statistics.

Collisions occurred in 17% of rollator accidents, more than three times more in comparison to pedestrians in general (Sweden: 5%, *Carlsson & Svensson, 2015*). Furthermore, collisions involving motor vehicles (cars, trucks, buses) occurred most frequently while reversing (54%), more than seven times more frequent in comparison to pedestrians in general (USA: 6.5%, *Stutts et al., 1996*; France: 6.9%, *Brenac & Fournier, 2018*). These results confirm previous studies showing that older pedestrians are being overrepresented in reversing accidents (*Dunbar et al., 2004; Brenac & Fournier, 2018*). Advancing age, and the inherent deterioration of the faculties such as hearing and vision, may be an influencing factor in elderly pedestrians failing to notice moving traffic (*Dunbar et al., 2004*). The elderly are also at an increased risk of being hit by a reversing vehicle due to cognitive abilities diminishing in relation to dementia related neuropathology (*Gorrie et al., 2008*). Foreseeing unpredictable reversing movements of vehicles in car parks can also be challenging for elderly pedestrians (*Sheppard & Pattinson, 1986*). Lastly, their declining physical abilities may hinder their ability to move out of the way

of a reversing vehicle fast enough to avoid being hit (*Oxley & Fildes, 1999; Dunbar et al., 2004; Charness et al., 2012*). In collisions, head injury was the dominant AIS 3+ injury among rollator users (36%), followed by torso (33%), leg (16%) and hip (15%) injuries (Figure 5f). This differs from pedestrians in general, where hip/leg injury is the dominant AIS 3+ injury (36%), followed by torso (36%) and head (24%) injuries (*Berntman, 2015*). The high frequency of reversing collisions among rollator users (54%) may possibly contribute to these differences. It is thus important to study specific VRU groups separately in order to identify risk situations that otherwise might be missed. To address the problem with reversing accidents, the European New Car Assessment Programme (EuroNCAP), has introduced a new test scenario, the Autonomous Emergency Braking (AEB) Reverse, in which a pedestrian dummy is positioned behind a reversing car (*EuroNCAP, 2020*).

Gender differences are notable in the present study, females being involved in more than twice as many accidents than males, which may have several explanations. For example, a greater percentage of females than males use rollators (as well as walking sticks and wheelchairs—*Gell et al., 2015*). Furthermore, females are more likely to develop mobility limitations in advanced age (*Gill et al., 2013*) and are also at a greater risk of falling (*Rosen et al., 2013*). In addition, it is more common for females to experience a fear of falling (*Peterson et al., 2017*). However, some studies suggest that males are more prone to a adopt riskier behaviour (*Gelbard et al., 2014*). Consequently, much of the research has been focused on females (see for example *Liu et al., 2015; Rosenberg et al., 2013*), although suggestions for more research into fall accidents in males has been issued (*Resnik et al., 2010*).

Human factors are important to study due to rollator users representing a multifaceted, often slow-moving, subgroup of older pedestrians/VRUs, which may contribute to increased complexity in injury prevention strategies. The results of this study show that the average age of rollator users involved in accidents was above 80 years (Figure 6d, A4d). The high average age can be explained by the large proportion of the elderly in Sweden who use some form of walking aid (*The Swedish Handicap Institute, 2014*). Physiological ageing as well as not doing enough physical activity (disuse) will hamper the different functions required for balance (postural control—*Sherrington & Tiedemann, 2015*). Balance may also be affected by certain medical diagnoses and pharmaceutical drugs, which may vary according to dosage, metabolism and interactions. Falls have been particularly associated to psychoactive medicines affecting mental processes, i.e., perception, consciousness, cognition as well as mood and emotions, Generally, physiotherapy will improve many of the affected functions (*Sherrington & Tiedemann, 2015*). Elderly users of assistive devices generally experience balance and/or mobility problems, are frail, and thus at increased risk of falling and sustaining injuries in the event of a fall (*West et al., 2015*). Consequences of falling include a fear of falling, social isolation, functional restriction, depression, institutionalisation and hospitalisation (*Cruz et al., 2019*).

Vehicle factors, i.e., rollator factors, include the technical performance, function, and construction, such as brakes, mechanics, and wheels, as well as adjustments and stability. Rollators used both indoors and outdoors must be small and flexible enough to manoeuvre indoors, yet stable enough to be used outdoors. However, using the same rollator both indoors and outdoors may result in significant amounts of dirt, such as mud or slush being brought indoors if the outdoor surface is inadequate. Consequently, in some weather conditions users may avoid bringing their rollator outdoors, thereby impeding their mobility. One alternative is

to use different rollators indoors (smaller, easily manoeuvred) and outdoors (robust with larger set of wheels), each tailored to the respective environment (Figure A1 in Appendix). However, further adjustments may be required to make a rollator suitable for outdoor use, such as visibility, lights, tyre size, slope brake function, mass distribution, stability, seating and secure storage arrangements. Transporting goods on a rollator while bringing the equipment over a curb is challenging for someone whose strength and/or balance is already compromised. A further factor that needs to be considered is that the private rollator market in countries such as Sweden is rather extensive, hence it remains unknown whether skills are satisfactory for adapting the rollator as well as providing suitable advice for users' personal needs.

Environmental factors can be challenging for older pedestrians as many experience problems in situations demanding effective cognitive processing, fast responses and quick actions (*Oxley et al., 2004*). To date, the following environments have been deemed hazardous: intersections, multi-laned roads, fast moving traffic, crossings not allowing enough time for slow walkers, as well as curbs, congested and/or poorly maintained/uneven footpaths/roads (*Oxley et al., 2004; Rosenberg et al., 2013*). Inadequate snow/ice clearance may severely restrict mobility and cause difficulties in the daily lives of people with disabilities (*Carlsson & Lundälv, 2019*). The present study shows that single accidents and collision events were evenly distributed over the year (Figure 6a). These figures differ from pedestrians in general, who had been subject to almost twice as many accidents during the winter (*Carlsson & Svensson, 2015*). A plausible explanation would be that rollator users avoid outdoor activities during winter, possibly due to difficulties manoeuvring the rollator in snowy/icy conditions or coldness. This may also explain why collisions involving VRUs most frequently occur during summer (Figure A4a), since this mode of transport is more common during the summer season (for example cycling—*Transport Analysis, 2015*). Differences in ground level, which may result in lifting and pushing the rollator in synchronicity with body movements, is a destabilising factor (*Bateni & Maki, 2005; Cruz et al., 2019*). The present study shows that almost 60% of single accidents were due to ground conditions (curb 29%; trip 9%; stuck 2%; surface 19%), while many of the collision events occurred while crossing a road (21% zebra crossing; 8% crossing). Previous research has identified curbs as a major obstacle and cause of accidents for rollator users (*Rosenberg et al., 2013; Jiraporn et al., 2018; Chippendale & Lee, 2018*). The question arises as to the design of pavements (with curbs), and if any alternatives for separating pedestrians from other road users, while simultaneously safeguarding effective drainage and guidance for the visually impaired, are available? Furthermore, surprisingly many collision events involving rollators occurred in car parks (29%), which is two times more in comparison to pedestrians in general (Finland: 13%—*Malin et al., 2020*). A contributing factor may be that drivers operating vehicles in car parks may lack awareness of elderly pedestrians with disabilities (*Oxley et al., 1997; Rosenberg et al., 2013*). However, with recent developments in the field of active safety, i.e., autonomous brakes, the risk of this type of collision will likely decrease (*EuroNCAP, 2020*). Another way to improve the mobility and independence among rollator users would be to facilitate availability of resting places and adequate light sources (*Rosenberg et al., 2013*). Poor lighting may aggravate depth perception, which may increase the risk of accidents and prevent people from going out after dark.

Social/System factors are important to consider in order to reduce the risk of accidents for this particular category of road users, i.e., persons with motor impairments. This may include activities for disabled VRUs, appropriate prescription by healthcare professionals, proper

training programmes, and effective and adequate maintenance routines, as highlighted in previous studies (*Liu, 2009; Charette et al., 2018; Carlsson & Lundälv, 2019*). Studies have established that the majority of rollator users (61%—*Liu, 2009*) have either personally acquired their walking support equipment, or been helped by family or friends, rather than by a medical expert. However, selecting an unsuitable rollator or using it inaccurately may, beside the risk of falling, result in excessive energy consumption, damage to the joints through extra pressure and make walking unstable (*Charette et al., 2018; Cruz et al., 2019*). Any training provided must include different common tasks undertaken daily (*Costamagna et al., 2019*). "*Training should take place within the activities the frail elderly person usually performs and within their known environment"* (*Skymne et al., 2012*).

A limitation of this study is the lack of specific variables regarding rollators in the STRADA database; there is no unified way of categorising these walking aids. A 'free text search' was performed in order to identify relevant cases, hence, there is a risk that cases might have been overlooked due to different spelling or vocabulary in the database. In order to allow follow-up studies, more information is needed about the circumstances preceding falls, both to better understand the contributing risk factors and to develop specific and effective fall prevention strategies (*Stevens et al., 2009*). Thus, data regarding vehicle (rollator) and environmental factors should be included in the accident and injury registration (*Berg et al., 2017; Carlsson & Lundälv, 2019*). Injury severity and costs for falls would then be distinguishable for different environments (*Berg et al., 2017*). Beside the lack of injury data, research into rollator users' experience of accidents and perceived risks in the traffic environment is also limited. In addition, enhancing the knowledge about travel patterns and exposure for rollator users, would be valuable.

The present study has shown that more in-depth research is needed into rollator related accidents, both with regard to single accidents and collision events. Future work should follow up accident and injury developments and further improve the quality of rollator related accident data in order to take appropriate action. Improved vehicle stability and design, increased usage of safety equipment, proper training programmes, effective maintenance services, development of a supporting infrastructure would all contribute to increased safety and mobility for rollator users.

5 Conclusions

- The number of accidents relating to rollator users in Sweden is increasing. Further increase is to be expected due to the aging population.
- Single accidents are more common than collision events, and the injuries are at least as serious. The vast majority of single accidents was due to falls.
- Collision events involving motorised vehicles were commonly due to reversing. A noticeably high proportion of collisions involving motor vehicles occurred in car parks and on (zebra) crossings.
- Females dominate the injury statistics in single accidents, collisions, as well as fatal outcome.
- AIS 3+ injuries were dominated by head and torso injuries in collision events, and hip fractures in single accidents.

CRediT contribution statement

Anna Carlsson: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualisation, Project administration, Funding acquisition. **Jörgen Lundälv**: Validation, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Visualisation.

Declaration of competing interests

The authors report no competing interests.

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About the authors

Anna Carlsson has more than 20 years of experience in Biomechanics and Injury Prevention within the area of Traffic Safety, with a special focus on women and the elderly, people with reduced mobility and vulnerable road users. She has one Master's Degree in Engineering Physics and one in Education, as well as a PhD in Machine and Vehicle Systems. Furthermore, Anna has experience of working in academia as well as in industry.

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APPENDIX

Figure A1. a) Indoor rollator (Futura 600) also suitable for outdoor use on even surfaces. b) Outdoor rollator (Carl-Oskar 62) suitable for both terrain and paved surfaces. Both rollators are of model year 2020. Photos: Ingemar Larsson, Hjälpmedelscentralen, Västra Götalandsregionen, Sweden.

Collisions – VRU (n=28)

Males / Females / Unknown:
18% / 64% / 18%

Collisions – Car/Truck/Bus (n=322)

Males / Females:
25% / 75%

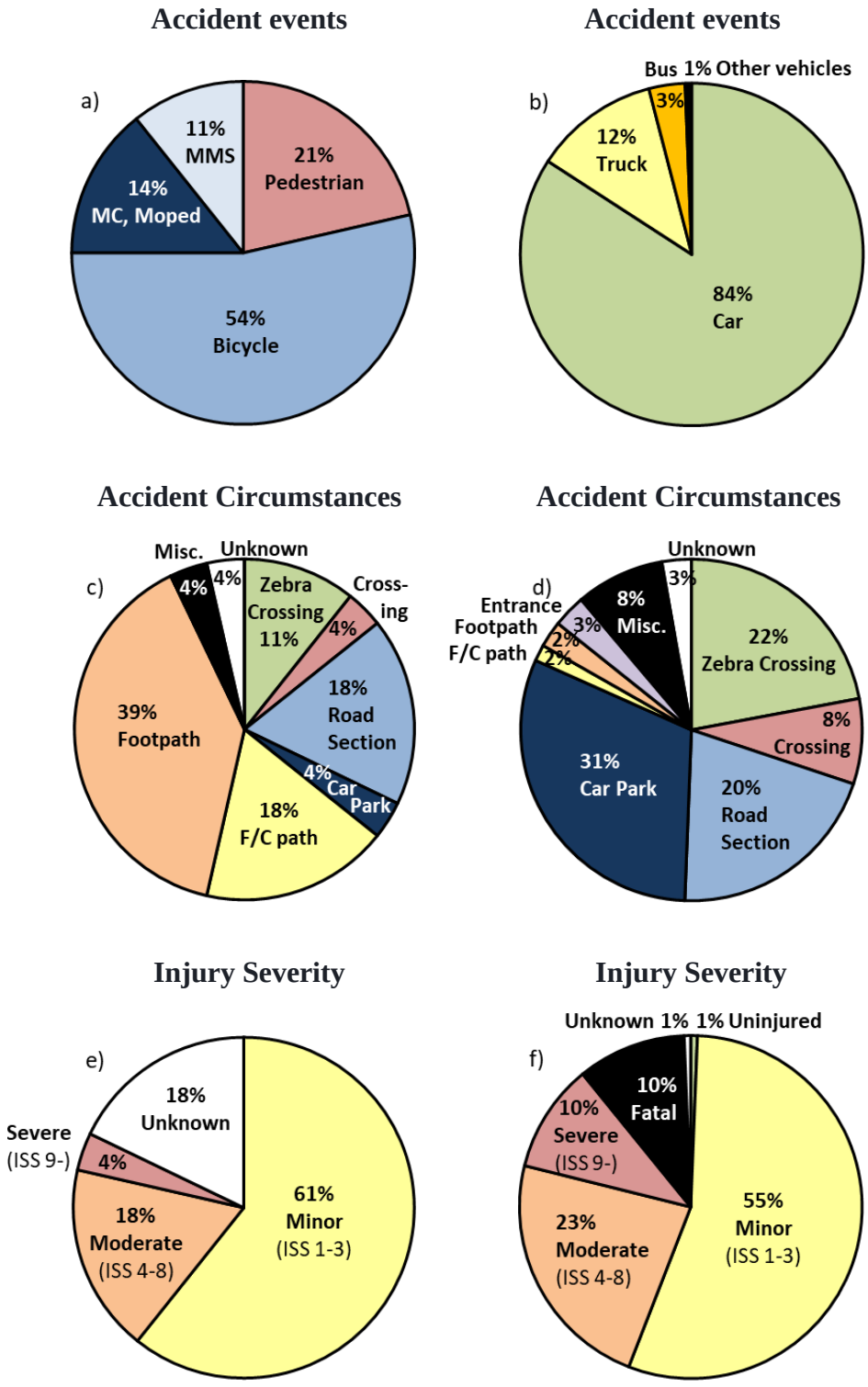


Figure A2. a) VRU and b) car/truck/bus collision accident events; c) VRU and d) car/truck/bus collision accident circumstances; e) VRU and f) car/truck/bus collision accidents injury severity

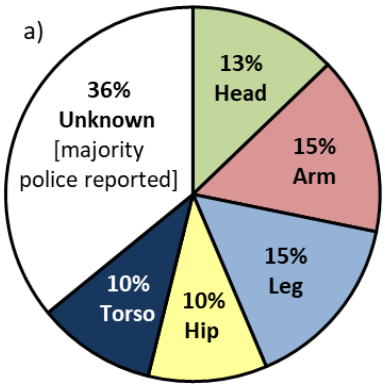
Collisions – VRU (n=28)

Males / Females / Unknown:
18% / 64% / 18%

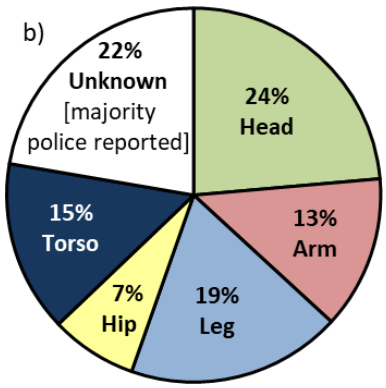
Collisions – Car/Truck/Bus (n=322)

Males / Females:
25% / 75%

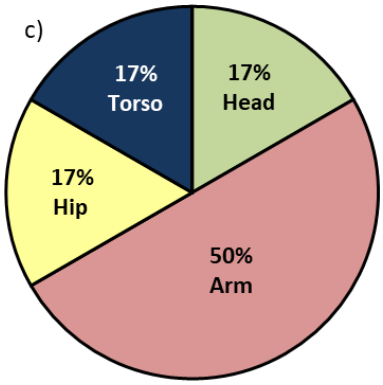
All Reported Injuries (n=25)
[14 cases unknown]



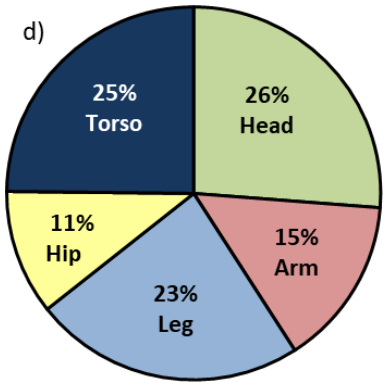
All Reported Injuries (n=540)
[155 cases unknown]



AIS 2+ Injuries (n=6)



AIS 2+ Injuries (n=286)



AIS 3+ Injuries (n=135)

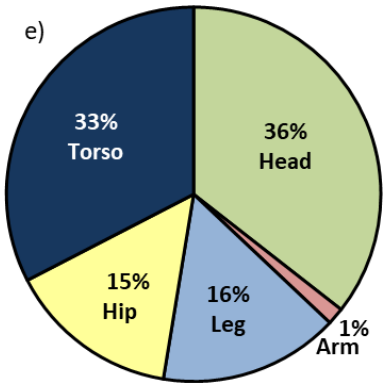


Figure A3. Injured body parts based on: all injuries in a) VRU and b) car/truck/bus collision accidents; AIS 2+ injuries in c) VRU and d) car/truck/bus collision accidents; AIS 3+ injuries in e) car/truck/bus collision accidents

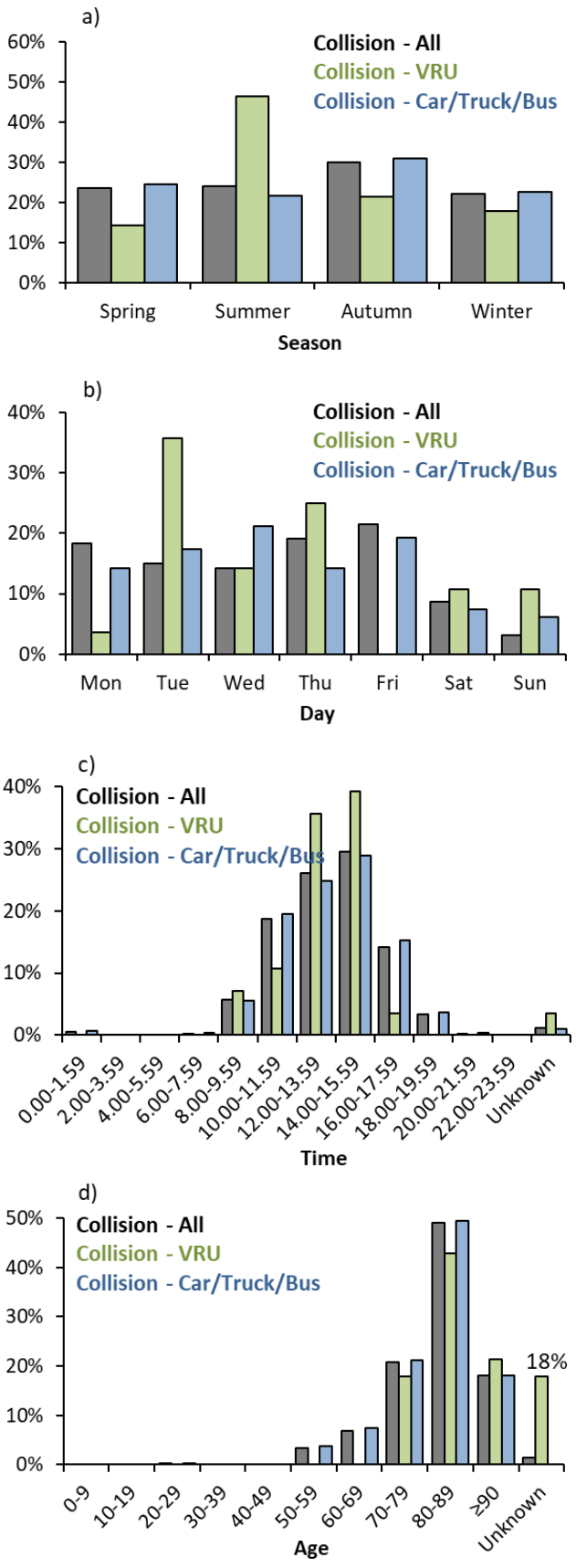


Figure A4. The distribution of a) season, b) day, c) time, and d) age of the driver in powered mobility devices (PMD collisions. Grey bars: all collisions (n=352), green bars: VRU collisions (n=322), blue bars: car/truck/bus collisions (n=28)