# Classification of Work-Related Cycling Crashes in Sweden 2018–2022

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***Abstract*** The objective of this study was to classify work-related bicycle crashes for two occupations: couriers and home carers. Injurious bicycle crashes reported by employers in Sweden between 2018 and 2022 were classified into crash type and circumstances based on free-text descriptions. In total, 1,194 crashes were classified: 441 couriers and 753 home carers. Couriers (80% male, median age 29 years) and home carers (79% female, median age 38 years) predominantly rode conventional bicycles (89% vs. 75%). Extremity injuries were frequent (76% vs. 62%), followed by head (6% vs. 10%), and torso, back or spine (11% vs. 7%) injuries. They often crashed due to loss of grip (27% vs. 21%), loss of balance (19% vs. 22%), or collisions (13% vs. 17%). Crash circumstances included slippery surfaces (37% vs. 27%), material failure (13% vs. 11%) or human factors (4% vs. 7%). The majority of crashes were single-cyclist crashes; 92% for couriers and 87% for home carers.

There were significant differences between couriers and home carers with regard to injury distribution, crash type and circumstances. Significant gender differences were seen with regard to crash type but not circumstances. Crash types varied depending on injured body part and season. Employers ought to apply occupation-specific preventive strategies.

***Keywords*** Accident statistics, bicycle crash, crash classification, occupational injury, single bicycle crashes.

## I. INTRODUCTION

Cycling has long been promoted as an environmentally friendly means of transport. The age of climate change demands a move from fossil fuel to renewable energy transportation, and it is expected that work-related bicycle journeys will increase in many occupations [1]. Occupational traffic safety research has traditionally focussed on groups requiring a professional driver's licence, such as heavy goods vehicle, taxi and bus drivers. Simultaneously, several countries have seen a decline in injuries sustained in car crashes but not in bicycle crashes [2-3]. As part of the vulnerable road user group, cyclists face hazardous traffic conditions without much protection apart from bicycle helmets. Hence, occupational safety must consider cycling as a risk and develop strategies to prevent work-related bicycle injuries. To do that, it is essential to understand how crashes occur.

In Sweden, between 73% and 85% of bicycle crashes in hospital admissions or police-reported data involve single-cyclist crashes, making them the most common type of bicycle crash [4-6]. However, it is likely that the true percentage of single crashes is higher as under-reporting of cycling crashes is common [7]. Frequently reported types of single crashes include cycling into potholes, pavements or tram tracks [8-9].

No published study on work-related bicycle crashes was found. For motorised vehicles, stress and fatigue are factor that may influence traffic safety [10-13]. In Sweden, the two occupations with the highest number of reported work-related bicycle injuries were social work activities, i.e. home care assistance for the elderly and disabled, and postal and courier services [14]. Both occupations often work on tight schedules and it remains unknown if stress affects the types of crash and injury they experience. In a survey for home carers, 38% of those who cycled between care recipients had been involved in a crash at work [15]. For comparison, 13% of Norwegian bicycle owners reported a crash [8].

A Norwegian study compared the bicycle crash risk for men and women, as well as between conventional bicycles and electric bicycles [8]. It found that the crash risk for females using electric bicycles was higher, partly because of unfamiliarity with electric bicycles. In home care, many employees have recently arrived in the country and have little or no previous experience of bicycles. There are several Swedish volunteer initiatives teaching female immigrants to cycle in order to enhance their work opportunities. Another study [16] examined hospital-

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reported bicycle crashes in Sweden and found differences between men and women with regard to crash type and injury location. Women were more likely to skid on ice or snow and to lose balance at low speed, while men crashed at higher speeds and more often going downhill. Men more frequently injured the upper extremities and women the lower extremities. That study also observed age differences, whereby older cyclists sustained more hip and upper leg injuries and were more often involved in crashes due to loss of balance.

Is there a difference between private and work-related bicycle crashes? Do crashes vary for different occupations? The aim of this study was to test the hypothesis that crash characteristics vary for different occupations. This was achieved by classifying injury-producing bicycle crashes that occurred while working for two occupations: the male-dominated role of courier, and the female-dominated role of home carer.

## II. METHODS

This study classified bicycle crashes using a dataset of work-related injuries reported by employers in Sweden. It has received approval from the Swedish Ethical Review Authority (2023-02963-01).

### *Data Source*

Cases involving work-related bicycle injuries were identified in a database at the Swedish Work Environment Authority (Arbetsmiljöverket, AV). It holds data on work-related injuries reported by the employer with regard to any employee on sick-leave for at least one day, as well as fatal injuries. Swedish employers are required by law to report work-related injuries to the AV database. Only injury cases involving employees legally employed by Swedish companies are included. Fatalities occurring in Sweden are registered for all employees, irrespective of in which country the employer's business is registered.

Data collection and classification were performed by AV according to the methodology of the European Statistics on Crashes at Work [17]. Hence, traffic crashes were included in the database if they involved persons whose occupational activity was carried out mainly on public roads, e.g. couriers, or who frequently or occasionally travelled on public roads, e.g. in connection with health care provided at a patient's home. Data collection did not include commuting, cases involving deliberately self-inflicted injuries or those caused by medical conditions. For full details on the classification method, please refer to the Eurostat methodology [17].

The AV database included variables that described the characteristics of the injured person (age, sex, employment status), the injury (type of injury, injured body part, expected duration of sick-leave), the enterprise (economic activity, size of enterprise), and the crash (time, date, deviation and associated material agent, free-text description of the crash event). In this context, the variable deviation described the abnormal event leading up to the crash [17].

### *Data Selection*

Inclusion criteria:

- Crash occurred during the five-year period between 1 January 2018 and 31 December 2022.
- The employer's industrial classification, defined by the economic activity according to the European classification NACE Revision 2 [18], was either Postal and courier activities (H53) or Social work activities without accommodation (Q88). Hereafter referred to as couriers and home carers.
- The material agent associated with the deviation was either bicycle, electric bicycle, or electric kick-bike. (An electric kick-bike can also be called an e-scooter. It features a standing platform, handlebars, small wheels, and with a speed limit of 20 km/h it falls under the Swedish legislation for bicycles.)

Exclusion criteria:

- Cases lacking free-text description of the crash event.
- Non-traffic cases, e.g. crashes occurring in industrial, indoors or fenced-off areas.

### *Data Analysis*

Crash characteristics were classified based on the free-text description of the crash event with regard to location of crash, type of crash, circumstances, and helmet use. Table I lists the categories developed based on a first analysis of 100 random cases, equally distributed between couriers and home carers, and the classification presented in [16]. Each case has been categorised by one location, one type of crash, and up to three circumstances. If other road users were involved in the crash, their crash type and circumstances were not analysed.

Results were presented using descriptive statistics, including frequency and proportions. Differences in cyclist occupation and gender were tested with the Pearson Chi-Square test on an Alfa-level 0.05 with regard to data variables and above-mentioned crash characteristics. The same test was used to evaluate relationships between crash type and injured body part, as well as crash type and whether the crash occurred in the winter or summer.

TABLE I

CATEGORIES FOR CLASSIFICATION OF CRASHES

| Location | Crash type | Circumstances |
|---|---|---|
| 1- Road traffic, unspecified | 0- Unspecified | 0- Unspecified |
| 1A- Bicycle path | 1- Loss of grip | 1- Evasive manoeuvre |
| 1B- Pedestrian area | 2- Collision | 2- Braking |
| 1C- Road | 2A- Collision with bicycle or kick-bike | 3- Turning |
| 1D- Parking | 2B- Collision with car | 4- Material failure |
| 1E- Square | 2C- Collision with other vehicle | 4A- Bicycle |
| 1F- Other | 2D- Collision with stationary object | 4B- Bicycle equipment |
| | 2E- Collision with pedestrian | 4C- Poorly equipped bicycle |
| | 3- Locked-wheel/powertrain | 4D- Clothing or personal accessories |
| | 3A - Caused by own equipment | 5- Slippery surface |
| | 3B - External cause | 5A- Ice or snow |
| | 3C - Caused by harsh braking | 5B- Water |
| | 4- Loss of balance | 5C- Gravel |
| | 4A- At standstill | 5D- Leaves |
| | 4B- Because of high speed | 5E- Mud |
| | 4C- Because of obstacle | 5F- Tram tracks |
| | 5- Accident with stationary bicycle | 6- Poor surface conditions |
| | 5A- Bicycle fell | 7- Human factors |
| | 6- Other | 7A- Dizziness or sickness |
| | | 7B- Distraction |
| | | 7C- Stress |
| | | 8- Poor visibility |
| | | 9 - Weather (e.g. strong wind) |

## III. RESULTS

### *Study Population*

The study population comprised cyclists who had been injured in a crash while working as couriers or home carers, resulting in at least one day off work. During the five-year study period, 2018–2022, there were 441 reported work-related courier bicycle crashes and 753 reported home care bicycle crashes (Table II). There were no reported fatalities. For couriers, 80% of the injured employees were male and 34% held a permanent position. For home carers, 79% of the injured employees were female and 67% held a permanent position. The median age was 29 years for couriers and 38 years for home carers (Table II). This difference was significant ($p<0.001$). For both occupations, females were older than males ($p<0.001$).

The majority of courier crashes occurred in the urban areas of Stockholm (65%), followed by the counties Västra Götaland (11%) and Skåne (7%). The home care crashes were more evenly distributed over Sweden: Skåne and Stockholm had most crashes with 17% each, followed by Västra Götaland (13%) and Östergötland (7%). The remaining shares of crashes occurred in other Swedish counties.

The majority of cases involved conventional bicycles: 89% for couriers and 75% for home carers (Table II). Electric bicycles were more common ($p<0.001$) for home carers (22%) than couriers (11%). Less than 4% of cases involved electric kick-bikes. With regard to bicycle type, no significant gender differences were found for the different occupations. Helmet use was classified for less than 5% of cases, too few for any meaningful analysis.

TABLE II

| STUDY POPULATION | Couriers, H53 (n=441) | | | Home carers, Q88 (n=753) | | |
|---|---|---|---|---|---|---|
| | **Male** | **Female** | **Total** | **Male** | **Female** | **Total** |
| | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) |
| *Gender*** | | | | | | |
| Male | 351 (100) | - | 351 (79.6) | 158 (100) | - | 158 (21) |
| Female | - | 90 (100) | 90 (20.4) | - | 595 (100) | 595 (79) |
| *Employment status**§§* | | | | | | |
| Permanent | 97 (27.6) | 53 (58.9) | 150 (34) | 99 (62.7) | 407 (68.4) | 506 (67.2) |
| Temporary | 253 (72.1) | 37 (41.1) | 290 (65.8) | 59 (37.3) | 188 (31.6) | 247 (32.8) |
| Own company | 1 (0.3) | 0 (0) | 1 (0.2) | 0 (0) | 0 (0) | 0 (0) |
| *Age**§§^^* | | | | | | |
| 17–25 years | 111 (31.6) | 29 (32.2) | 140 (31.7) | 52 (32.9) | 122 (20.5) | 174 (23.1) |
| 26–35 years | 153 (43.6) | 18 (20) | 171 (38.8) | 41 (25.9) | 130 (21.8) | 171 (22.7) |
| 36–45 years | 43 (12.3) | 12 (13.3) | 55 (12.5) | 28 (17.7) | 103 (17.3) | 131 (17.4) |
| 46–55 years | 21 (6) | 15 (16.7) | 36 (8.2) | 22 (13.9) | 117 (19.7) | 139 (18.5) |
| 56+ years | 23 (6.6) | 16 (17.8) | 39 (8.8) | 15 (9.5) | 123 (20.7) | 138 (18.3) |
| *Type of bicycle*** | | | | | | |
| Manual bicycle | 316 (90) | 76 (84.4) | 392 (88.9) | 124 (78.5) | 438 (73.6) | 562 (74.6) |
| Electric bicycle | 33 (9.4) | 13 (14.4) | 46 (10.4) | 30 (19) | 133 (22.4) | 163 (21.6) |
| Electric kick-bike | 2 (0.6) | 1 (1.1) | 3 (0.7) | 4 (2.5) | 24 (4) | 28 (3.7) |
| *Injured Body Part**^* | | | | | | |
| Head | 21 (6) | 7 (7.8) | 28 (6.3) | 12 (7.6) | 63 (10.6) | 75 (10) |
| Neck | 1 (0.3) | 2 (2.2) | 3 (0.7) | 3 (1.9) | 13 (2.2) | 16 (2.1) |
| Back and spine | 20 (5.7) | 9 (10) | 29 (6.6) | 5 (3.2) | 23 (3.9) | 28 (3.7) |
| Torso and internal organs | 15 (4.3) | 4 (4.4) | 19 (4.3) | 6 (3.8) | 18 (3) | 24 (3.2) |
| Upper extremities | 100 (28.5) | 23 (25.6) | 123 (27.9) | 67 (42.4) | 154 (25.9) | 221 (29.3) |
| Lower extremities | 173 (49.3) | 37 (41.1) | 210 (47.6) | 40 (25.3) | 203 (34.1) | 243 (32.3) |
| Whole body | 16 (4.6) | 6 (6.7) | 22 (5) | 21 (13.3) | 96 (16.1) | 117 (15.5) |
| Lack of Information | 5 (1.4) | 2 (2.2) | 7 (1.6) | 4 (2.5) | 25 (4.2) | 29 (3.9) |
| *Type of Injury**§§^* | | | | | | |
| Unknown or unspecified | 24 (6.8) | 17 (18.9) | 41 (9.3) | 13 (8.2) | 65 (10.9) | 78 (10.4) |
| Wounds and superficial injuries | 184 (52.4) | 26 (28.9) | 210 (47.6) | 27 (17.1) | 131 (22) | 158 (21) |
| Bone fractures | 49 (14) | 11 (12.2) | 60 (13.6) | 46 (29.1) | 112 (18.8) | 158 (21) |
| Dislocations, sprains and strains | 68 (19.4) | 24 (26.7) | 92 (20.9) | 43 (27.2) | 146 (24.5) | 189 (25.1) |
| Concussion and internal injuries | 10 (2.8) | 5 (5.6) | 15 (3.4) | 4 (2.5) | 30 (5) | 34 (4.5) |
| Other injuries | 16 (4.6) | 7 (7.8) | 23 (5.2) | 25 (15.8) | 111 (18.7) | 136 (18.1) |
| *Expected Leave of Absence*** | | | | | | |
| 1–3 days | 175 (49.9) | 39 (43.3) | 214 (48.5) | 48 (30.4) | 182 (30.6) | 230 (30.5) |
| 4–14 days | 121 (34.5) | 38 (42.2) | 159 (36.1) | 66 (41.8) | 245 (41.2) | 311 (41.3) |
| More than 14 days | 55 (15.7) | 13 (14.4) | 68 (15.4) | 44 (27.8) | 168 (28.2) | 212 (28.2) |

Note: **p<0.001, *p<0.05 regarding differences between couriers (H53) and home carers (Q88). §§p<0.001, §p<0.05 regarding gender differences within couriers. ^^p<0.001, ^p<0.05 regarding gender differences within home carers.

The injury distribution was significantly different (p<0.001) for the two occupations (Table II). Significant gender differences (p<0.05) were found for home carers with regard to injury distribution, but not for couriers. For both occupations, the majority of injuries were located in the extremities. In couriers, the lower extremities were injured in almost half of all cases (48%), followed by injuries to the upper extremities (28%), torso or back (11%), including spinal or internal organ injury, and head or neck (7%). In home carers, the lower extremities were injured in 32% of cases and the upper extremities in 29%, followed by injuries to the whole body (16%), and head or neck injuries (12%).

The types of injury differed significantly for the two occupations (p<0.001) and gender (p<0.001 for couriers, p<0.05 for home carers). Wounds and superficial injuries were common for couriers (48%), followed by dislocation, strains and sprains (21%) as well as bone fractures (14%). Home carers saw a more even distribution of injury types between dislocations, strains and sprains (25%), bone fractures (21%), and wounds and superficial injuries (21%). Concussions were reported relatively rarely (3–5%). The expected leave of absence was slightly higher for injuries in home carers compared to couriers (p<0.001). Sick-leave longer than two weeks was expected in 28% of home carer cases and in 15% of courier cases.

***Crash Classification***

Table III presents the results for the crash classification with regard to location, type of crash, and circumstances. Twelve percent of the cases lacked information on both type of crash and circumstances. The most common crash types included loss of grip, loss of balance, and collision, and the most common circumstances were slippery surface, braking, and material failure. Crashes occurred slightly more often in the winter for couriers (59% October–March) and were distributed evenly between summer and winter for home carers. There was a significant relationship between crash type and time of year (p<0.001) for both occupations (Fig. 1).

There were significant occupational and gender differences regarding crash type (p<0.05, Table III). Crash circumstances differed significantly for occupations (p<0.05), but not for gender in either occupation (Table III). There was adequate information in the free-text descriptions to classify both type of crash and circumstances for approximately two-thirds of the cases.

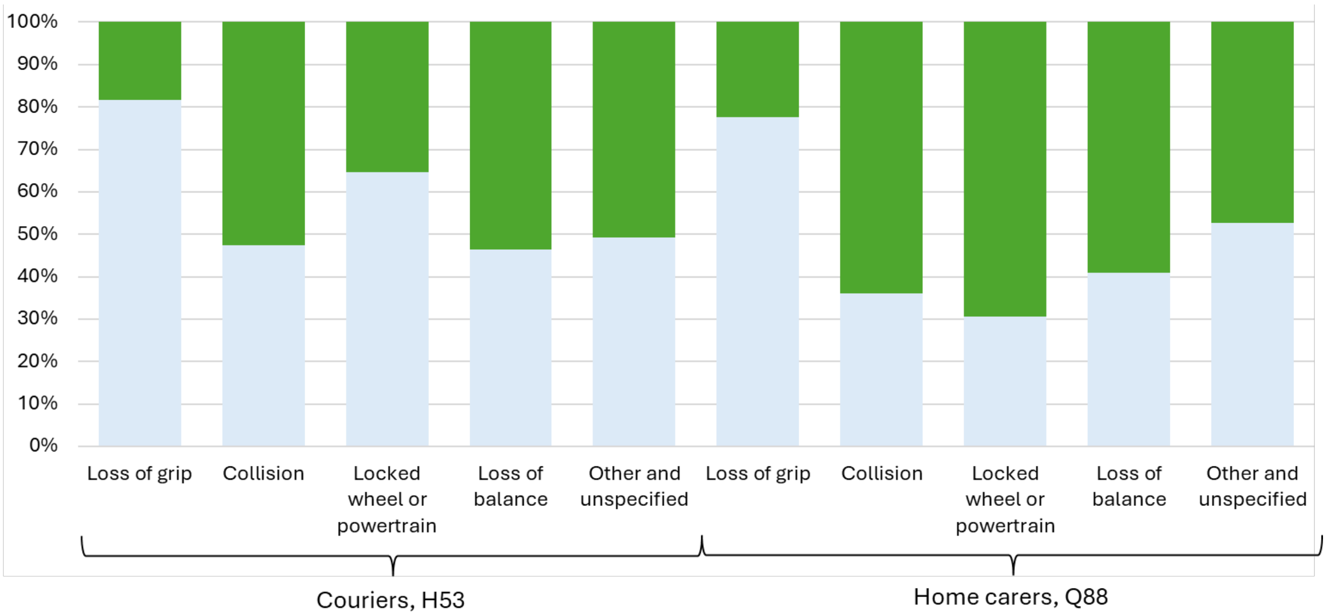


Fig. 1. Distribution of crash types in winter (October–March, light blue) and summer (April–September, green), p<0.001 for couriers (H53) and home carers (Q88).

TABLE III

TYPE OF CRASH

| | Couriers, H53 (n=441) | | | Home carers, Q88 (n=753) | | |
|---|---|---|---|---|---|---|
| | **Male** | **Female** | **Total** | **Male** | **Female** | **Total** |
| | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) |
| *Location*§ | | | | | | |
| Bicycle path | 56 (16) | 5 (5.6) | 61 (13.8) | 19 (12) | 71 (11.9) | 90 (12) |
| Pedestrian area | 4 (1.1) | 4 (4.4) | 8 (1.8) | 3 (1.9) | 9 (1.5) | 12 (1.6) |
| Road | 47 (13.4) | 12 (13.3) | 59 (13.4) | 21 (13.3) | 62 (10.4) | 83 (11) |
| Parking | 0 (0) | 2 (2.2) | 2 (0.5) | 4 (2.5) | 3 (0.5) | 7 (0.9) |
| Other or unspecified | 244 (69.5) | 67 (74.4) | 311 (70.5) | 111 (70.3) | 450 (75.6) | 561 (74.5) |
| *Crash type**§^ | | | | | | |
| Loss of grip | 104 (29.6) | 16 (17.8) | 120 (27.2) | 31 (19.6) | 121 (20.3) | 152 (20.2) |
| Collision | 47 (13.4) | 12 (13.3) | 59 (13.4) | 18 (11.4) | 107 (18) | 125 (16.6) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Locked wheel/powertrain | 31 (8.8) | 3 (3.3) | 34 (7.7) | 29 (18.4) | 59 (9.9) | 88 (11.7) |
| Loss of balance | 61 (17.4) | 23 (25.6) | 84 (19) | 30 (19) | 134 (22.5) | 164 (21.8) |
| Stationary bicycle | 1 (0.3) | 3 (3.3) | 4 (0.9) | 1 (0.6) | 12 (2) | 13 (1.7) |
| Other and unspecified | 107 (30.5) | 33 (36.7) | 140 (31.7) | 49 (31) | 162 (27.2) | 211 (28) |
| *Circumstances** | | | | | | |
| Evasive manoeuvre | 42 (12) | 5 (5.6) | 47 (10.7) | 28 (17.7) | 59 (9.9) | 87 (11.6) |
| Braking | 53 (15.1) | 4 (4.4) | 57 (12.9) | 21 (13.3) | 70 (11.8) | 91 (12.1) |
| Turning | 35 (10) | 9 (10) | 44 (10) | 12 (7.6) | 54 (9.1) | 66 (8.8) |
| Material failure | 47 (13.4) | 8 (8.9) | 55 (12.5) | 16 (10.1) | 68 (11.4) | 84 (11.2) |
| Slippery surface | 127 (36.2) | 34 (37.8) | 161 (36.5) | 36 (22.8) | 170 (28.6) | 206 (27.4) |
| Poor surface conditions | 8 (2.3) | 3 (3.3) | 11 (2.5) | 5 (3.2) | 23 (3.9) | 28 (3.7) |
| Human factors | 15 (4.3) | 4 (4.4) | 19 (4.3) | 12 (7.6) | 43 (7.2) | 55 (7.3) |
| Poor visibility | 6 (1.7) | 1 (1.1) | 7 (1.6) | 6 (3.8) | 15 (2.5) | 21 (2.8) |
| Weather | 4 (1.1) | 3 (3.3) | 7 (1.6) | 2 (1.3) | 11 (1.8) | 13 (1.7) |
| Other or unspecified | 100 (28.5) | 41 (45.6) | 141 (32) | 57 (36.1) | 221 (37.1) | 278 (36.9) |

Note: **$p<0.001$, *$p<0.05$ regarding differences between couriers (H53) and home carers (Q88). §§$p<0.001$, §$p<0.05$ regarding gender differences within couriers. ^^$p<0.001$, ^$p<0.05$ regarding gender differences within home carers.

Loss of grip accounted for 27% of cases in couriers and 20% in home carers (Table III). The majority of crashes with loss of grip were due to slippery surfaces (94% H53, 99% Q88, Table IV). Slippery surfaces were ice or snow ($n_{H53}$=49, $n_{Q88}$=49), water ($n_{H53}$=12, $n_{Q88}$=17), gravel ($n_{H53}$=11, $n_{Q88}$=21), leaves ($n_{H53}$=4, $n_{Q88}$=11) or tram tracks ($n_{H53}$=4, $n_{Q88}$=0). Loss of grip occurred in combination with braking (18% H53, 10% Q88, Table IV) and turning (17% H53, 18% Q88, Table IV). Loss of grip was rarely connected to material failures. The majority of crashes involving loss of grip occurred between October and March (82% H53, 78% Q88), see Fig. 1.

TABLE IV
DISTRIBUTION OF CIRCUMSTANCES FOR CRASHES DUE TO LOSS OF GRIP

| | **Couriers H53 (n=114)** n (%) | **Home carers Q88 (n=147)** n (%) |
|---|---|---|
| Evasive manoeuvre | 8 (7.0) | 6 (4.1) |
| Braking | 21 (18.4) | 14 (9.5) |
| Turning | 19 (16.7) | 26 (17.7) |
| Material failure | 3 (2.6) | 2 (1.4) |
| Slippery surface | 107 (93.9) | 145 (98.6) |
| Poor surface conditions | 0 (0) | 1 (0.7) |
| Human factors | 2 (1.8) | 3 (2.0) |
| Poor visibility | 2 (1.8) | 2 (1.4) |

Locked-wheel or powertrain failure, for example due to harsh braking or an object locking one wheel, accounted for 8% of cases in couriers and 12% in home carers (Table III). There were significant occupational differences ($p<0.05$) with regard to circumstances (Table V). For couriers, locked-wheel or powertrain failures were caused by external factors in 41% of cases, harsh braking in 29%, and own equipment in 18% (Table V). For home carers, 60% of locked-wheel or powertrain failures were caused by harsh braking, 20% by own equipment, and only 8% by external factors (Table V). Material failure was connected to 23% of cases in couriers and 29% in home carers (Table V). Slippery surfaces were frequent for couriers (42%) but not for home carers. Human factors contributed to 3% of courier cases and to 11% of home carers cases. Crashes involving locked-wheel or powertrain failures most often occurred in winter for couriers (65% October–March) and in summer for home carers (69% April–September), see Fig. 1.

TABLE V

DISTRIBUTION OF CRASH TYPES AND CIRCUMSTANCES FOR CRASHES DUE TO LOCKED WHEEL OR POWERTRAIN FAILURE

| **Type of crash, subcategory** | **Couriers H53 (n=34)** | **Home carers Q88 (n=88)** | **Circumstances*** | **Couriers H53 (n=31)** | **Home carers Q88 (n=73)** |
|---|---|---|---|---|---|
| | n (%) | n (%) | | n (%) | n (%) |
| Caused by own equipment | 6 (17.6) | 18 (20.5) | Evasive manoeuvre | 4 (12.9) | 28 (38.4) |
| External cause | 14 (41.2) | 7 (8.0) | Braking | 10 (32.3) | 30 (41.1) |
| Caused by harsh braking | 10 (29.4) | 53 (60.2) | Turning | 1 (3.2) | 2 (2.7) |
| | | | Material failure | 7 (22.6) | 21 (28.8) |
| | | | Slippery surface | 13 (41.9) | 5 (6.8) |
| | | | Poor surface conditions | 3 (9.7) | 5 (6.8) |
| | | | Human factors | 1 (3.2) | 8 (11.0) |
| | | | Poor visibility | 0 (0) | 2 (2.7) |

Note: *$p<0.05$ regarding differences between couriers (H53) and home carers (Q88).

Loss of balance accounted for 19% of courier cases and 22% of home carer cases (Table III). It usually occurred due to obstacles (55% H53, 49% Q88) and less frequently at standstill (6% H53, 12% Q88). Approximately a quarter of all cases involving loss of balance were connected to evasive manoeuvres (25% H53, 24% Q88, Table VI) and almost as often occurred in combination with material failure (21% H53, 23% Q88, Table VI). Loss of balance due to slippery surfaces were more frequent for couriers than for home carers (25% H53, 14% Q88, Table VI), as was turning (27% H53, 14% Q88, Table VI). Human factors contributed more often to the home care cases (21%) compared to couriers (12%), although not significantly. Poor surface conditions and braking were present for 14–17% of crashes involving loss of balance (Table VI). Crashes with loss of balance were relatively evenly distributed over the year: 46% and 41% occurred from October to March for couriers and home carers, respectively (Fig. 1).

TABLE VI

DISTRIBUTION OF CIRCUMSTANCES FOR CRASHES DUE TO LOSS OF BALANCE

| | **Couriers H53 (n=52)** | **Home carers Q88 (n=111)** |
|---|---|---|
| | n (%) | n (%) |
| Evasive manoeuvre | 13 (25.0) | 26 (23.4) |
| Braking | 7 (13.5) | 17 (15.3) |
| Turning | 14 (26.9) | 16 (14.4) |
| Material failure | 11 (21.2) | 25 (22.5) |
| Slippery surface | 13 (25.0) | 16 (14.4) |
| Poor surface conditions | 7 (13.5) | 19 (17.1) |
| Human factors | 6 (11.5) | 23 (20.7) |
| Poor visibility | 1 (1.9) | 4 (3.6) |

Collisions accounted for 13% of courier cases and 17% of home carer cases (Table III). In both occupations, approximately a third of the collisions were with cars (Table VII). Collisions with stationary objects were more common for couriers (37%) than for home carers (23%), while collisions with other bicycles were more common for home carers (37%) than for couriers (22%). For both occupations, only 2% comprised collisions with pedestrians. For couriers, collisions were often connected with evasive manoeuvres (40%). For home carers, poor visibility accounted for 28% of cases. Material failures contributed to 15% and 21% of collisions, respectively, for couriers and home carers. Human factors contributed to approximately a tenth of all collisions. Collisions were evenly distributed over the year for couriers (53% April–September) and most often occurred in summer for home carers (64% April–September, Fig. 1).

The type of crash was unspecified for 32% of courier cases and 28% of home carer cases (Table III). Material failure contributed to unspecified crashes in 37% of courier cases and 26% of home carer cases. Slippery surfaces were frequent circumstances for the unspecified cases (29% H53, 35% Q88). Braking presented in 20% of the unspecified crashes, evasive manoeuvres in 17% and turning less often (10% H53, 14% Q88).

TABLE VII
DISTRIBUTION OF COLLISION PARTNERS AND CIRCUMSTANCES FOR COLLISIONS

| **Collision partner** | **Couriers H53 (n=59)** | **Home carers Q88 (n=125)** | **Circumstances** | **Couriers H53 (n=20)** | **Home carers Q88 (n=43)** |
|---|---|---|---|---|---|
| | n (%) | n (%) | | n (%) | n (%) |
| Bicycle or kick-bike | 13 (22.0) | 46 (36.8) | Evasive manoeuvre | 8 (40.0) | 11 (25.6) |
| Car | 21 (35.6) | 43 (34.4) | Braking | 2 (10.0) | 11 (25.6) |
| Other vehicle | 1 (1.7) | 5 (4.0) | Turning | 2 (10.0) | 9 (20.9) |
| Stationary object | 22 (37.3) | 29 (23.2) | Material failure | 3 (15.0) | 9 (20.9) |
| Pedestrian | 1 (1.7) | 2 (1.6) | Slippery surface | 4 (20.0) | 5 (11.6) |
| | | | Poor surface conditions | 0 (0) | 0 (0) |
| | | | Human factors | 2 (10.0) | 5 (11.6) |
| | | | Poor visibility | 4 (20.0) | 12 (27.9) |

Human factors contributed to a higher frequency of crashes for home carers than for couriers (7% vs. 4%, Table III). The couriers predominantly made mistakes, such as misjudging the distance to a stationary object or turning at too high speed. For home carers, there was a relatively even distribution between mistakes, distraction, stress and dizziness or sickness.

Figure 2 illustrates the relationship between the type of crash and the injured body part (p<0.001), showing no significant difference between couriers and home carers (p>0.05). Head or neck injuries were sustained mostly in collisions (25%), loss of balance (18%), locked wheel or powertrain failure (17%), loss of grip (11%) or unspecified crashes (30%). Torso or back injuries, including spinal injuries, were caused mostly by loss of grip (26%), collisions (14%), loss of balance (11%) or unspecified crashes (39%). Extremity injuries were most frequently caused by loss of grip (25%), loss of balance (22%), or unspecified crashes (30%). Injuries to the whole body were mostly caused by loss of balance (24%), collisions (22%), loss of grip (17%), or unspecified crashes (30%).

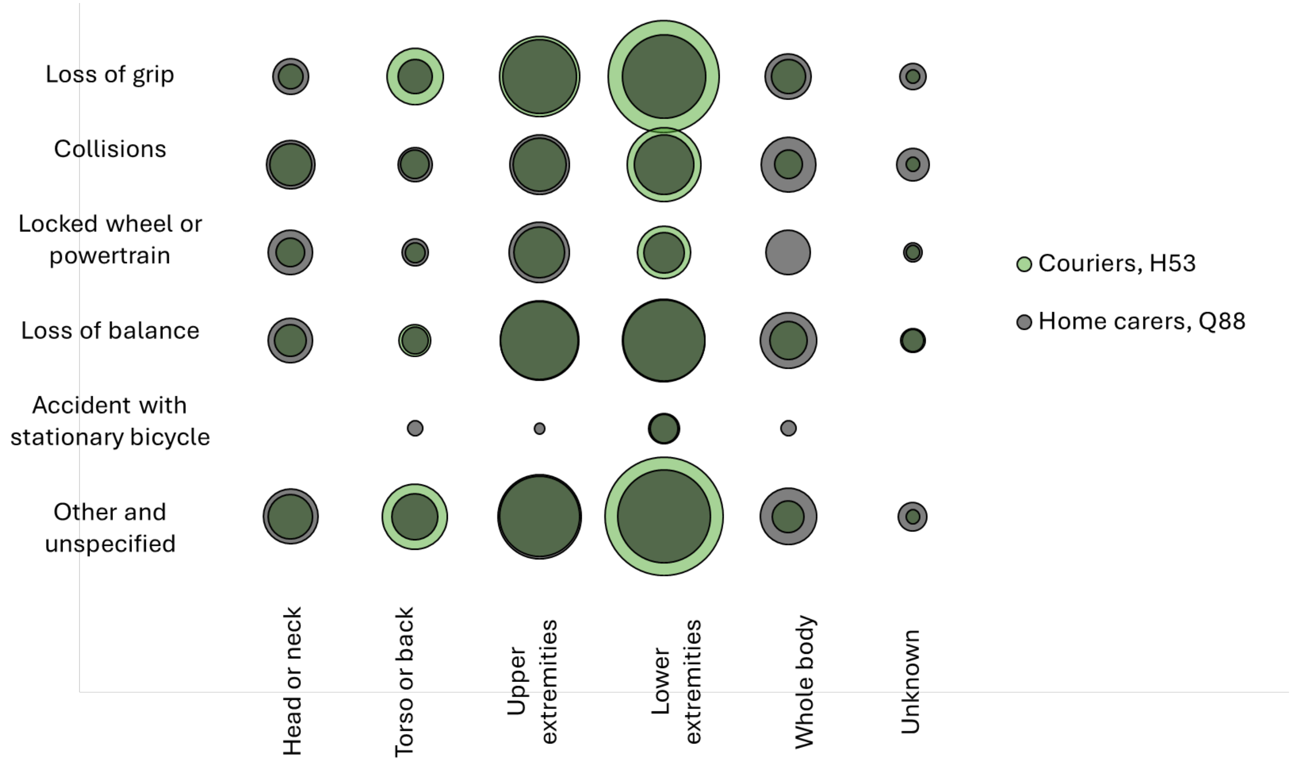


Fig. 2. Type of crash per injured body part (p=0.06 for H53, p<0.004 for Q88). Bubble size indicates the percentage of cases for the total of all cases in couriers (H53, green) and home carers (Q88, grey).

## IV. DISCUSSION

This study describes work-related bicycle crashes and classifies them into types of crash and circumstances. The hypothesis that crash types and circumstances vary for different occupations was shown to be true, as courier and home carer crashes present statistically significant differences ($p<0.05$) with regard to crash types and circumstances. This result indicates that employers ought to apply occupation-specific strategies to prevent work-related bicycle crashes and to reduce injuries. The results from this study can be used to identify and prioritise preventive strategies for occupational safety of employees who are required to travel by bicycle.

The work-related bicycle crashes had a high proportion of extremity injuries (67%), 10% head and neck injuries, and only 5% back or spine and 4% chest injuries. These figures differ from previously published studies. A previous study [19] found head or neck injuries in 67% and chest injuries in 47% of cases, however it studied only severely injured patients. A similar study in Italy found 53% head trauma [20]. For bicycle crashes resulting in hospital visits in Sweden, 48% of injuries were to the back or spine and 23% to the lower extremities [21]. The injuries in the AV data were predominantly minor, which could explain the differences compared to previous publications regarding the injury distribution.

We found subtle significant differences ($p<0.001$) in injury distribution between the two occupations. The male-dominated couriers presented more lower extremity injuries (48% H53, 32% Q88) and more chest, back or spine injuries (11% H53, 7% Q88), than the female-dominated home carers. The rate of upper extremity injuries was similar (28% H53, 29% Q88). Head and neck injuries were less frequent for couriers (7% H53, 12% Q88). One study [16] saw that the distribution of injuries differed significantly between gender and age groups. It found that men injured the shoulder and upper arms more often than women (28% vs. 11%). Women injured the spine or back (16% vs. 8%) and lower leg (30% vs. 7%) more often than men. Similarly, for home carers, males had more upper extremities injuries ($p<0.05$). There were no significant gender differences for couriers. This suggests that the gender differences in injury distribution reported previously may be more related to cycling factors, such as traffic environment, speed or the cyclist's stress level, rather than to gender, which is similar to findings for car safety [22]. In a work context, many of these factors apply irrespective of the gender of the employee; when cycling privately, factors can differ depending on gender, due to traditional or cultural values.

It was more common for home carers to have crashes due to harsh braking (7% vs. 2%) or loss of balance at standstill (2% vs. 1%). A Norwegian study [8] explained the higher risk for females riding electric bicycles compared to conventional bicycles, by the cyclist being unfamiliar with electric bicycles. In Sweden, many immigrants who work in home care are novice cyclists (68% foreign born [23]). Based on the free-text descriptions, it was also evident that some employees were proficient cyclists but lacked experience of cycling on winter roads covered in snow and ice, which contributed to crashes. Slippery surfaces caused 31% of the work-related crashes. Note that [16] found 34% skidding on ice, snow or wet leaves for private cycling. In contrast to that study, the present study found fewer cases due to poor road surface conditions (3% compared to 6% in [16]) and more due to locked wheel or powertrain failures (10% compared to 6% in [16]).

Most of the work-related cycling crashes comprised single-cyclist crashes: 92% for couriers and 87% for home carers. These figures are slightly higher than presented in previous studies that focussed mainly on private cycling, based on Swedish hospital and police-reported data, comprising 70–85% single crashes [4-6][21], which may partly be explained by the larger percentage of low severity crashes in the AV database compared to hospital and police-reported data. This explanation is supported by an even lower percentage of single crashes for severely injured cyclists, 54% [19].

For work-related bicycle crashes, 5% comprised collisions with cars and 5% collisions with other cyclists. The proportion of car crashes was lower than studies on private cycling: 18% collisions with cars and 8% with other cyclists in a study of hospital data [21], 32% collisions with cars and 6% with other cyclists for severely injured patients [19]. A German study of cyclist collisions [1], based on police reports, found that the majority of opponents were cars (77%), and it is known that cyclist crashes are under-reported in police data [6], which may explain the differences for single-cyclist crashes and cyclist-to-cyclist collisions. However, for work-related crashes with head and/or neck injury the proportion of collisions was higher (29% H53, 24% Q88).

Loss of balance or loss of grip caused 44% of the crashes, which is comparable to 46% loss of control reported by [21], but much higher than the 7% loss of balance in [8]. That study [8] reported 61% of cases as falls (hit tram track, pavement, pothole) that in the present study would be distributed between lost balance because of poor road conditions and collision with stationary object, depending on the size of object. Hence, the two studies are not directly comparable.

The female-dominated home carers presented with more head injuries (10% Q88, 6% H53) than the male-dominated couriers, as well as more severe injuries, with expected sick-leave longer than two weeks (28% Q88, 15% H53). A parallel unpublished survey [15] found that helmet use for home carers was low, partly because of perceived sanitary issues when employees had to share helmets and secure storage of helmet was not available outside the homes visited. It is likely that the frequency of helmet wearing was much higher for couriers, supported by a French study that found more frequent helmet-wearing among couriers than private cyclists [24]. The differences in helmet-use frequency may partly explain the occupational differences in injury distribution. It is well known that helmets provide good protection against skull fractures and brain injury. Therefore, it is strongly recommended that employers require staff to wear helmets during work-related cycling trips and facilitate helmet use, for example by providing personal helmets for employees.

Material failure contributed to more than one in 10 work-related bicycle crashes. This has not been reported in previous studies on private cycling and indicates that the quality and maintenance of bicycles required for work must be improved. In both occupations, the most common faults were defective brakes or chain. For home carers, there were also issues connected to adjusting the bicycle to fit the individual, to reach the pedals, as well as loose saddles or handlebars. Couriers also presented cases of faulty kickstands. Crashes due to material failure could be prevented if employers ensure that good quality bicycles are purchased and routines for regular bicycle maintenance are established. If employees share bicycles, such as is often the case in home care [15], they must be trained in how to safely adjust the bicycle so that it fits them properly and must be provided adequate time in the work schedule to do so.

Lastly, a third of all crashes in this study were due to slippery surfaces, of which the vast majority occurred in the winter. With increasing reliance on cycling, maintenance of winter roads must be prioritised. One study [25] stressed the importance of winter road maintenance to avoid an escalation in cycling injuries as cycling in winter is expected to increase. Furthermore, [15] stressed the need for stud tyres in winter cycling. Changes in the climate have made it harder to predict weather conditions during the winter season in Sweden, and employers are recommended to implement a flexible approach to stud tyres in bicycle maintenance.

***Limitations***

The database used in this study was based on reporting from employers. Even though Swedish employers are required by law to report work-related injuries, underreporting of injuries is a limitation. Reasons for not reporting an injurious bicycle crash vary: employee stress and tight schedules may not allow sufficient time to report crashes, stigma of admitting to a “silly” bicycle crash, employers lacking sufficient safety routines for reporting injuries, or employees refusing absence from work while recovering from symptoms, to name a few.

Injuries were only included in the present study for employees legally employed by Swedish companies. Hence, employees employed by foreign companies were excluded even if they sustained an injury while working in Sweden.

## V. CONCLUSION

This study classified injury-producing bicycle crashes in the public road environment that occurred while working in Sweden. The male-dominated couriers and the female-dominated home carers had significant differences in injury distribution ($p<0.001$), crash type and circumstances ($p<0.05$). There were significant differences in crash types depending on the injured body part ($p<0.05$) and the time of the year the crash occurred ($p<0.05$). The results indicate that employers ought to apply occupation-specific injury strategies to prevent work-related bicycle crashes, provide training for novice cyclists, require and facilitate helmet use, minimise material failure with regular bicycle maintenance, take season and weather conditions into account when setting schedules and provide time for safe cycling and thus reduce the risk of mistakes due to stress.

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