Skademekanismer vid cykelolyckor som resulterat i frakturer

Slutrapport

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Innehåll

Syftet med projektet

Det huvudsakliga syftet med detta projekt är att på ett nytt sätt analysera data om cykelolyckor. Denna analys skall bland annat ligga till grund för riktlinjer för utformning av personskydd för cyklister och prioriteringar av åtgärder i cyklisters infrastruktur. Syftet skall uppnås genom att söka ut trafikolyckor i två befintliga nationella databaser, Svenska Frakturregistret (SFR) och STRADA (Swedish TRaffic Accident Data Acquisition), och sedan matcha dessa två dataset via personnummer. Då ges möjlighet att hitta samband mellan frakturtyper (SFR har detaljerad information om frakturer) och händelseförloppet vid olyckan (STRADA innehåller information om olyckshändelsen, fordonet, vägförhållande och dylikt).

Sammanfattning

Cyklister står för en stor andel skadade i trafiken. Olycksdataanalysen för cyklistens säkerhet och skydd bör baseras på ett representativt dataset för verkliga olyckor. Det här projektet syftade till att utforska mönstren för cyklisters frakturer, och faktorer som är förknippade med frakturer med högre svårighetsgrad.

Syftet uppnås genom att kombinera information om trafikolyckor och skador från två befintliga nationella databaser, Svenska Frakturregistret (SFR) och STRADA (Swedish TRaffic Accident Data Acquisition).

Resultaten från studien visar att bilförarna var oftast involverade i olyckor vilket resulterade i frakturer (37%), följt av motorcyklister (27,6%) och cyklister (15,4%). Vanliga frakturer skilde sig åt efter typ av trafikant, där cyklister oftare skadades i nedre armen jämfört med andra trafikanter, som bilförare, motorcyklister och fotgängare som mest drabbades av frakturer i nedre benet. Inom cyklister skilde sig också frakturer efter kön, vilket tyder på att kombination av olika motåtgärder kan behövas för att ge tillräckligt skydd för alla cyklister. I de analyserade uppgifterna var manliga cyklister med en genomsnittlig ålder av 49 de mest skadade cyklisterna. Olyckstyper bör undersökas ytterligare, särskilt i relation till könsskillnader. Det kan finnas behov av förbättrade skyddsstrategier när könsrelaterade skillnader beaktas. Skydd bör utformas för att ge god skyddsverkan i olika olyckstyper, vid olyckor med hög- och lågenergivåld, och vid olyckor med olika trafikanter.

Högenergifrakturer var oftast cyklistfrakturer i acetabulum (100%), bäcken (84,2%), ryggrad (75%) och skenben (70,3%). Högenergifrakturer var signifikant mindre vanliga i singelcykelolyckor (OR = 0.165) och olyckor med en annan cykel (OR = 0.148) än olyckor med bil.

Skydd bör utvecklas så att risken för frakturer är reducerad för alla kroppsregioner. Det finns därmed ett behov att noggrant analysera cykelolyckor för att bestämma förloppen som leder till fraktur; data som kan användas vid utveckling av skydd som är specifika för cyklister, som har god skyddsverkan för män och kvinnor eller som är utvecklade specifikt för endera av könet.

Status

- Ansökning om etisk prövning vid etikprövningsnämnden i Göteborg från 27 januari till 3 maj 2017 (datum på beslutet om godkännande).
- Ansökning hos Transportstyrelsen om datauttag från STRADA – datum för godkännande 23 maj 2017.
- Ansökning hos Frakturregistret om registeruttag från Svenska Frakturregistret – datum för godkännande 23 maj 2017.
- Ett dataset som motsvarade projektets kriterier sparades ut från respektive register. Samkörning av de två datamängderna genomfördes av Karin Bengtsson, Transportstyrelsen. Det färdiga datasetet levererades till Chalmers den 29 juni 2017 (dagen före semesterstart).
- Preliminär dataanalys med hjälp av Frakturregistret initierades.
- Lauren Meredith började arbeta i projektet – Oktober 2018.
- Dataanalys på Chalmers är kompletterat.
- Artikel är skickat till Traffic Injury Prevention och bifogat med slutrapporten.
- Slutrapporten är kompletterat.

Bakgrund

Enligt socialstyrelsens patientregister är det cyklismen som ger flest trafikskadade av alla trafikslag i Sverige (data från patientregistret, PAR1), dessutom med ihållande trend istället för avtagande som är fallet för personbilar. Rapporten Statistik över cyklisters olyckor, utgiven av VTI 2013 (Niska och Eriksson, 20132), beskriver olyckor med personskador då cykeln används som transportmedel. Rapporten visar också att cyklister framförallt råkar ut för singelolyckor. Den olyckstypen kommer sällan till polisens kännedom och man räknar därför med att det kan resultera i en underrapportering i Polisrapporttabellen i Strada (Swedish TRaffic Accident Data Acquisition); om patienten söker vård på annat sätt än via sjukhusens akutmottagningar kommer ingen registrering av fallet att göras alls. Niska och Eriksson (2013) förklarar också att ca 70% av de allvarliga skadorna från cykelolyckor är skador på arm, axel, ben eller höft; av de mycket allvarliga skadorna är 39% huvudskador men arm/axel/ben/höftskador står för hela 42%. Det finns därför anledning att titta närmare på skademekanismerna bakom dessa skador för att ge möjlighet att utforma personskydd även för dessa kroppsdelar. Standarden för motorcykelkläder skulle kunna vara tillämpbar, åtminstone i vissa delar, men det är oklart om skademekanismerna är jämförbara; det är nödvändigt att det finns ett underlag för att bestämma lastnivåer tillämpbara för en standard för skyddskläder för cyklister, motsvarande SS-EN 13595 för motorcykelkläder.

Beskrivning av metod och material

Under genomförandet av projektet representanter för Fordonssäkerhet på Chalmers och för Svenska Frakturregistret (SFR) på Registercentrum samarbetade kring dataanalys. Studiens syften uppnås genom att söka ut trafikolyckor i två befintliga nationella databaser, Svenska Frakturregistret (SFR) och Swedish TRaffic Accident Data Acquisition (STRADA), och sedan matcha personer i de två dataseten via personnummer. Då ges möjlighet att hitta samband mellan frakturtyper och händelseförlopp vid olyckor. En sådan analys har inte tidigare genomförts.

Resultatsammanfattning

Registrering av frakturer i SFR startade 2011 och har etappvis under 2012-2014 byggts ut till att omfatta samtliga frakturtyper i alla åldersgrupper. Undantaget är att på barn registreras enbart frakturer på de långa rörbenen. Frakturer på skalle och revben ingår inte heller medan

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1 https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/dokument-webb/ovrigt/halsodataregister-patientregistret-nyttan-med-register.pdf

2 Niska A och Eriksson J, 2013. Statistik över cyklisters olyckor Faktaunderlag till gemensam strategi för säker cykling. https://www.vti.se/sv/publikationer/pdf/statistik-over-cyklisters-olyckor-faktaunderlag-till-gemensam-strategi-for-saker-cykling.pdf

däremot kotfrakturer och bäckenfrakturer registreras. Täckningen i 2017 är ca 75% dvs 40 av ca 55 kliniker rapporterar till SFR.

I SFR registreras skadeorsak, skadetyp, skadedatum, frakturtyp kodat dels enligt ICD-10 men även i detalj klassificerat beroende på frakturutseende, behandlingsförlopp inklusive reoperationer och slutligen patientrapporterat utfall med jämförelse mellan baslinjedata före skadedatum (sk recallteknik) och efter ett år.

Frakturbehandling är en av de allra mest resurskrävande verksamheterna inom svensk hälso- och sjukvård (SFR Årsrapport 2014). En närmare studie av skademekanismer för frakturer möjliggörs då man kompletterar STRADA -data med data från SFR. Då STRADA anger skador i det akuta skedet saknas långtidsuppföljningen. SFR, med sina patientrapporterade hälsotillståndsindex, är en potentiell källa till att följa upp graden av rehabilitering. STRADA (Swedish TRaffic Accident Data Acquisition) är en nationellt representativ databas om trafikrelaterade olyckor som rapporteras via akutsjukhus (frivilligt) och polisen (lagstadgat). Denna databas innehåller data om person, skador och olyckstillfället. Informationen om skadorna är i form av koder, och skapas av särskilt utbildad personal baserat på patientens journal. Informationen ger bara begränsad insikt i hur skadan uppkommit.

Det totala STRADA-datasetet bestod av 12350 skadade personer registrerade i sjukhusjournaler och 78729 skadade personer registrerade i polisregister från alla trafikolyckor för olycksår 2014-2016. Det totala SFR-datasetet för de som skadades i vägolyckor mellan 2014 och 2016 bestod av 12371 personer med frakturskador. Totalt 15,8% av SFR-fallen kunde matchas mot STRADA (antingen sjukhus eller polis), vilket resulterade i ett totalt matchat dataset av 1960 personer med 2881 frakturer. Antalet frakturer för män och kvinnor var 61.1% respektive 38.9%. När cyklistolyckor extraherades från det matchade datasetet fanns det 284 cyklister som drabbades av 327 frakturer. Av detta hade 200 cyklister varit registrerade i polisregister och 139 cyklister varit registrerade i sjukhusjournaler. De flesta cyklistskadorna, inträffade från juni till augusti månad, med topp i augusti.

Bilförarna var oftast involverade i olyckor vilket resulterade i frakturer (37%), följt av motorcyklister (27,6%) och cyklister (15,4%). Vanliga frakturer skilde sig åt efter typ av trafikant, där cyklister oftare skadades i nedre armen jämfört med andra trafikanter, som bilförare, motorcyklister och fotgängare som mest drabbades av frakturer i nedre benet. Inom cyklister skilde sig också frakturer efter kön, vilket tyder på att kombination av olika motåtgärder kan behövas för att ge tillräckligt skydd för alla cyklister. I de analyserade uppgifterna var manliga cyklister med en genomsnittlig ålder av 49 de mest skadade cyklisterna.

Högenergifrakturer var oftast cyklistfrakturer i acetabulum (100%), bäcken (84,2%), ryggrad (75%) och skenben (70,3%). Högenergifrakturer var signifikant mindre vanliga i singelcykelolyckor (OR = 0.165) och olyckor med en annan cykel (OR = 0.148) än olyckor med bil.

Slutsatser

Procentandelen matchade data var låg, totalt 15,8% av SFR-fallen kunde matchas mot STRADA, men matchningsprocessen möjliggjorde analys av många faktorer inklusive detaljer om olyckan och efterföljande skador. I de analyserade uppgifterna var män med en genomsnittlig ålder av 49 mest förekommande av de skadade cyklisterna. Det fanns skillnader i skador baserat på ålder, kön och skadepartner, vilket indikerar att skydd mot olika frakturer måste utformas baserat på de olika skadescenarierna. Resultaten av denna studie kan vägleda utformningen av lämpliga skyddsanordningar för cyklister, samt vägleda vid prioritering av nya åtgärder, kampanjer och förordningar.

Erhållen trafiksäkerhetsnytta och hur spridning av resultatet avses ske

Vetenskaplig artikel som är bifogat med slutrapporten

Lauren Meredith, Jordanka Kovaceva, András Bálint "Mapping cyclist fractures cause and severity in Sweden: how do cyclists compare to other road users?", skickat till Traffic Injury Prevention (pending revisions).

SAFER-nätverk

Dess status och preliminära resultat ska presenteras på kompetensområdesmöten i SAFER-nätverk.

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Bilaga

Mapping fractures from traffic accidents in Sweden: how do cyclists compare to other road users?

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Abstract

Introduction: *Cyclists account for a large share of injured road users in traffic. The crash data analysis for cyclist safety and protection should be based on a representative dataset of real-world crashes. This manuscript aimed to explore the patterns of cyclists' fractures and factors associated with fractures of higher severity.*

Methods: *This paper exemplifies a methodology that combines injuries from a crash database, including both hospital and police reports and fracture registry database from orthopaedic centres nationally in Sweden.*

Results: *Cars occupants were most frequently involved in crashes resulting in fractures (37%), followed by motorcyclists (27.6%) and bicyclists (15.4%). Common fracture locations differed by the type of road user, where cyclists were more frequently fractured in the lower arm, compared to other road users, such as car drivers, motorcyclists and pedestrians who suffered mostly of fractures in the lower leg. Within cyclists, injuries also differed by gender, suggesting that combination of different countermeasures may be needed in order to provide sufficient protection for all cyclist. In the analyzed data, male cyclists with an average age of 49 were the most frequently fractured cyclists.*

Fractures of cyclists to the acetabulum (100%), pelvis (84.2%), vertebra (75%) and tibia (70.3%) were most frequently high energy fractures. Single bicycle incidents (OR=0.165) and collisions with another bicycle (OR=0.148) were significantly less likely to result in a high energy fracture than a collision with a car.

Conclusions: *The results of this study may guide the design of appropriate protective devices for the cyclists based on the different injury mechanisms and provide implications for prioritizing new countermeasures, campaigns, or regulations.*

Keywords
Bicycle; fracture; injury; transportation; cyclist

Introduction

In Sweden, crashes involving cyclists account for a higher proportion (45%) of hospital reported crashes than any other road user.[1] Fractures have been found to be the most common injury type to cyclists and Juhra et al.(2011), found that, while traumatic brain injury accounted for the largest proportion of cyclists admitted to hospital, fractures to the upper and lower extremity were the injuries with largest resource consumption as a result of major surgery.[2]

Niska and Eriksson (2013)[3] also explain that about 70% of the serious injuries, or those whose injuries are predicted to result in 1% permanent medical impairment (PMI 1%), from cycling crashes are damage to the arm, shoulder, leg or hip. Of the very serious injuries, those resulting in 10% permanent medical impairment (PMI 10%), 39% were head injuries; however, arm, shoulder, leg and hip injuries accounted for 42%. There is therefore a need to look more closely at these injuries to provide the possibility of designing personal protection also for these body parts.

The main purpose of this study was to analyze data on bicycle crashes which lead to fractures through linking multiple in-depth data registries including fracture registry information, police records and hospital records, providing a greater detail of information than has been examined before based on the individual registries. This analysis, among other things, will form the basis for guidelines for designing personal protection for cyclists and prioritizing measures in cyclists' infrastructure.

Two existing national databases formed the basis of this study, the Swedish TRaffic Crash Data Acquisition (STRADA) and the Swedish Fracture Register (SFR). STRADA was created in response to a governmental direction to the former Swedish Road Administration. The task was to establish a new national information system which should be able to collect all police reported road crashes and additionally include emergency hospital information about injuries sustained in road crashes.[4] SFR was developed by orthopaedic specialists affiliated with Sahlgrenska University Hospital, beginning in 2011. The purpose of the SFR is to provide data on outcomes of the fracture treatment and lay a solid foundation of knowledge concerning the effectiveness of Swedish fracture care.

These datasets provide unique information in relation to the fracture and the crash, which, when combined, provide in-depth information on the crash scenario and outcome. This gave the opportunity to find connections between fracture types and the energy of the fracture as SFR has detailed information on the fractures, and the crash conditions as described in STRADA, including road conditions, weather conditions, and crash location.

This study aimed to: 1) match two datasets, SFR with the STRADA database for various transport modes and describe the matched dataset; 2) examine fractures occurring to bicyclists after bicycle crashes based on both STRADA and SFR in terms of the circumstances under which these fractures occur and to whom they occur, and 3) examine factors associated with higher severity of fracture in the matched data.

Methods

Datasets

Two different datasets were involved in this study. The first dataset was STRADA, which is a national information system in Sweden that contains all police reported road crashes and emergency hospital admission data related to road crashes.

The Swedish police are obligated by law (SFS 1965:561, last update in SFS 2014:1244) to report every road crash which led to at least one personal injury. Reports are based on observations by police officers at the crash site. The type of police reported road crashes which are submitted to STRADA is regulated by law. The criteria for the police to report a road crash coincide with Sweden's official definition of a road crash. According to the Swedish government agency, Transport Analysis, a road crash in Sweden is defined:

- to be a crash which has occurred in traffic on a road
- to involve at least one vehicle in motion
- to involve at least one personal injury.

The hospitals on the other hand report voluntarily. The reporting criteria for hospitals is to report everyone who seeks medical attention because of a road crash or a crash that occurred in the public traffic environment. This does not require that an injury is found. Additionally, it is necessary that a patient consents to the transmission of the hospital report to STRADA.[5] The data is then based on patient self-reported information.

Police and hospital reports are matched using Swedish personal identity numbers of involved persons, the crash time and location by the Swedish Transport Agency. The Swedish Transport Agency manages the data collection and storage. There is not a 100% match between hospital and police cases, but all collected cases are kept in the database, regardless of whether it contains only hospital or police data.

The Swedish Fracture Register (SFR) was the second dataset used in this study. This dataset contains information on fractures provided by medical professionals and includes details on the type and severity of fractures as well as treatment and surgical procedures undertaken. Additionally, patients are asked to complete follow-up questionnaires providing information of long-term effects of the fracture. Cases are those patients treated at and reported to SFR via about 35 of Sweden's 55 orthopaedic clinics, therefore it consists of only those patients requiring orthopaedic care. Information was provided to SFR through medical notes and patient questionnaires.[6]

A closer study of injury mechanisms is made possible when supplementing STRADA data with data from SFR, which among other things contains very detailed information on the fracture.

Data from the two registers were selected based on the following criteria: transport related incidents in Sweden and persons of all genders from 16 years of age. Available data included those crashes occurring from January 2014 to December 2016, which involved most recent data when this study began. Cases from the two different datasets were then matched by the Swedish Transport Agency, using the Swedish Personal Identity Number to match SFR cases with STRADA.

Variables

The variables available in each dataset can be seen in Table 1. All injury details used in the analysis were taken from SFR, while crash details were taken from the relevant database in STRADA.

Table 1. Available variables from SFR and STRADA and the different data reporting procedures in STRADA.

	STRADA Hospital	**STRADA Police**	**SFR**
Age	yes	yes	yes
Gender	yes	yes	yes
Date of incident	yes	yes	yes
Vehicle type	yes	yes	no
Impact partner	yes	yes	no
Fracture location	yes	no	yes
Fracture severity	yes	no	yes
Fracture complexity	no	no	yes
Energy of fracture	no	no	yes
Surgical procedures	no	no	yes
Long-term follow-up	no	no	yes
Geographical region	yes	yes	no
Environment (urban/rural)	no	yes	no
Place (intersection/footpath /cycleway/roundabout)	yes	yes	no
Road type	no	yes	no
Weather	no	yes	no
Road conditions	no	yes	no
Light conditions	no	yes	no

Analysis

Descriptive analysis was conducted on available variables in the full SFR dataset to obtain baseline fracture data, the matched STRADA and SFR dataset to examine fractures within all transport types and only cyclists within the matched dataset. Geographical locations were normalised by the total population for each region in 2016 as reported by Statistics Sweden.[7]

Significant associations between variables were explored using chi-squared tests of independence in both the total matched dataset and for cyclists only. Specifically, associations between age and gender with the location of fracture and age and gender with transport mode.

High and low energy fractures were used as a measure of higher and lower severity fractures. The energy of the fracture was defined in SFR, where a 'high energy' fracture was one resulting from a traffic crash involving a fall from height and a 'low energy' fracture involved a fall in the same plane. These definitions are analogous to 'high-side' and 'low-side' motorcycle crashes, where 'low-side' refers to a loss of traction, resulting in the rider falling with the bike and skidding along the roadway and the term 'high-side' refers to any crash when the rider is thrown up and off the bike. High-side motorcycle crashes are typically associated with higher severity.

Logistic regression was used to examine factors influencing the occurrence of a high energy fracture in crash involving cyclists.

Analysis was conducted with IBM SPSS Statistics 24.[8]

Results

Description of the data

The total STRADA dataset consisted of 12,350 injured persons recorded based on hospital records and 78,729 injured persons based on police records from all road crashes (Figure 1). The total SFR dataset of those fractured in road crashes between 2014 and 2016 consisted of 12,371 fractured persons. A total of 15.8% of the SFR cases were able to be matched against STRADA (either hospital or police), resulting in a total matched dataset of 1,960 fractured persons, amongst them suffering 2,881 fractures. When cyclist crashes were extracted from the matched dataset, there were 284 fractured cyclists who suffered 327 fractures among them. Of this, 200 cyclists had police report information and 139 cyclists had hospital information.

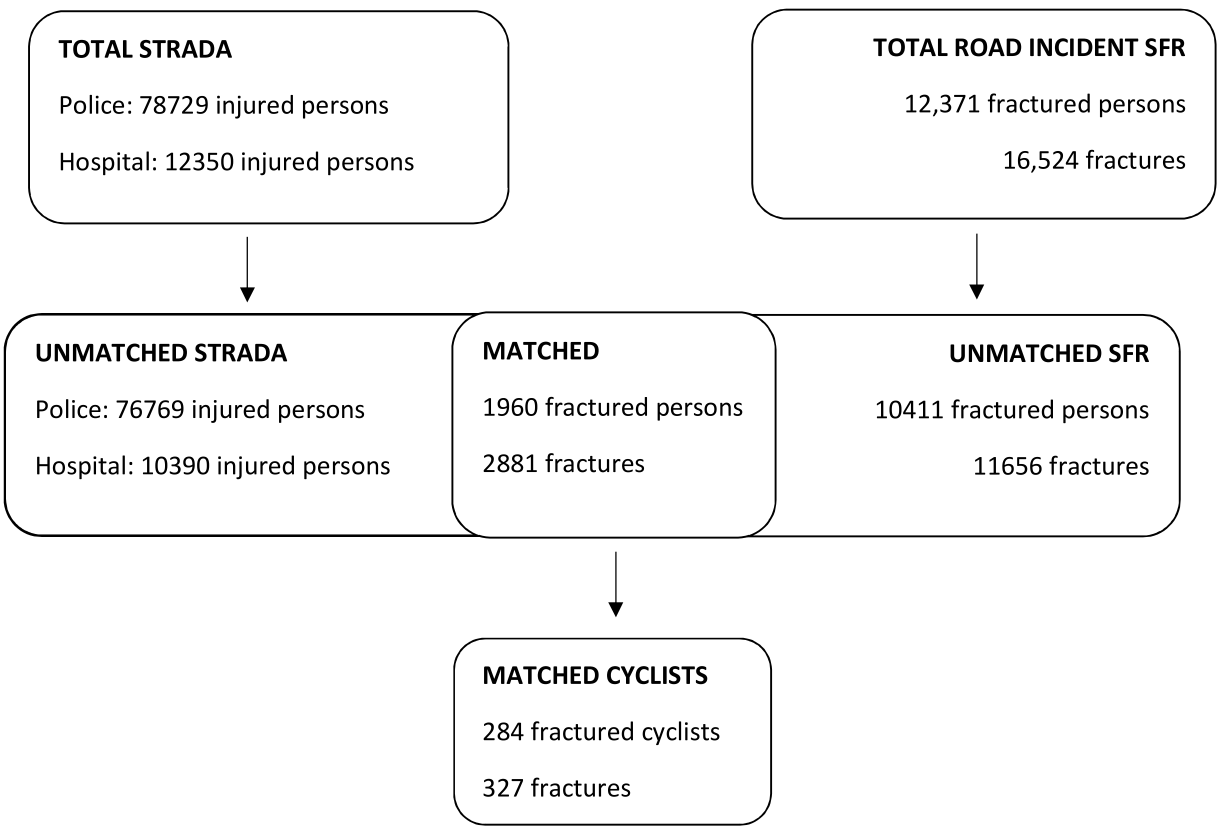


Figure 1. Number of injured persons and injuries between 2014 and 2016 for the different datasets in all crashes and matched dataset.

Total Swedish Fracture Register

The total SFR dataset related to road crashes involved 12,371 patients who suffered a fracture on at least one body part, which consisted of 14,537 fractures. Most of those fractured persons suffered only one (n=10,883) or two fractures (n=1,114), but some had up to 15 fractures from the crash.

As seen in Figure 2, fractures resulting from a crash in a bus (median age 70) and train or tram (median age 73) involved older patients, whereas fractures following a motorcycle crash more frequently involved younger patients (median age 33). The median age of pedestrians and cyclists who had a fracture were in the 50-60-year-old age range, while three-wheelers, cars and trucks were in the 40-year-old age range. These differences, as well as several results presented below, may be driven by differences in exposure; this will be elaborated further in the "Discussion" section.

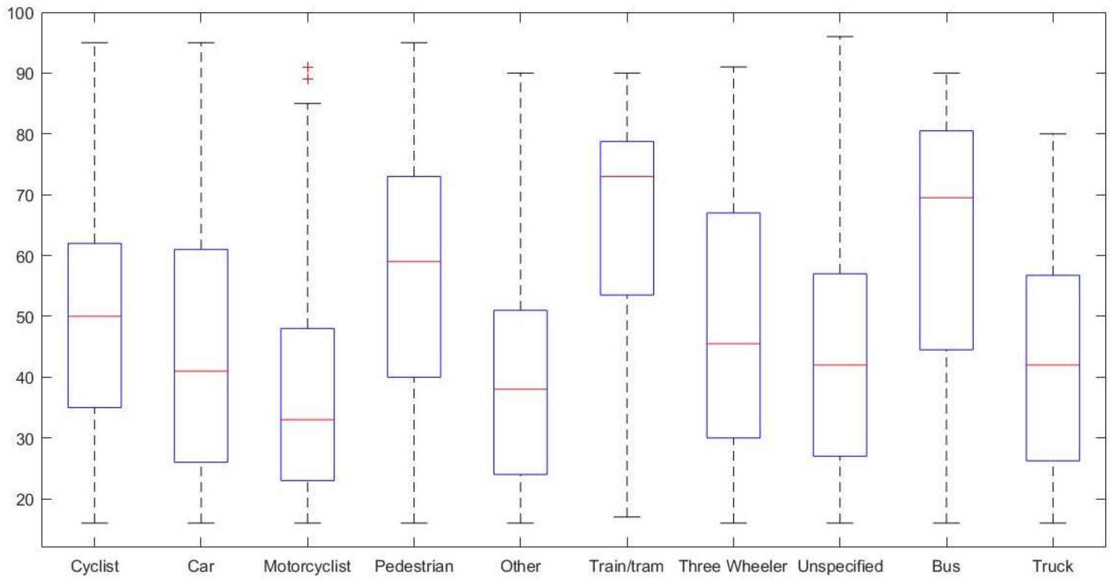


Figure 2. Boxplot of the age of fractured persons for each transport mode in SFR.

Total matched dataset

The total matched dataset involved 1,960 patients who suffered a fracture on at least one body part and among them, they suffered 2,352 fractures. The age and gender distribution can be seen in Figure 3. The highest proportion of fractures were to those aged between 21-25 (11.7%). Males dominated overall (61.1%) and within age groups, except for those over the age of 76.

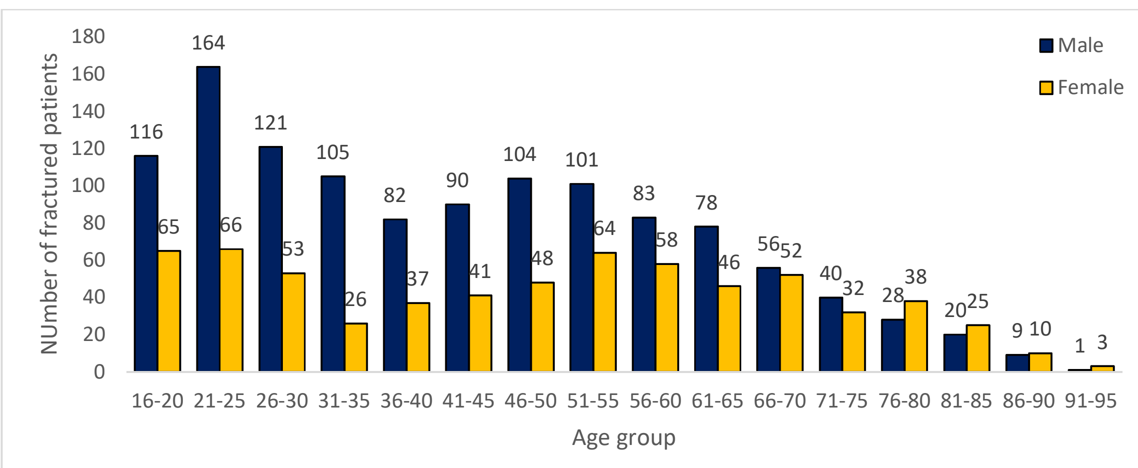
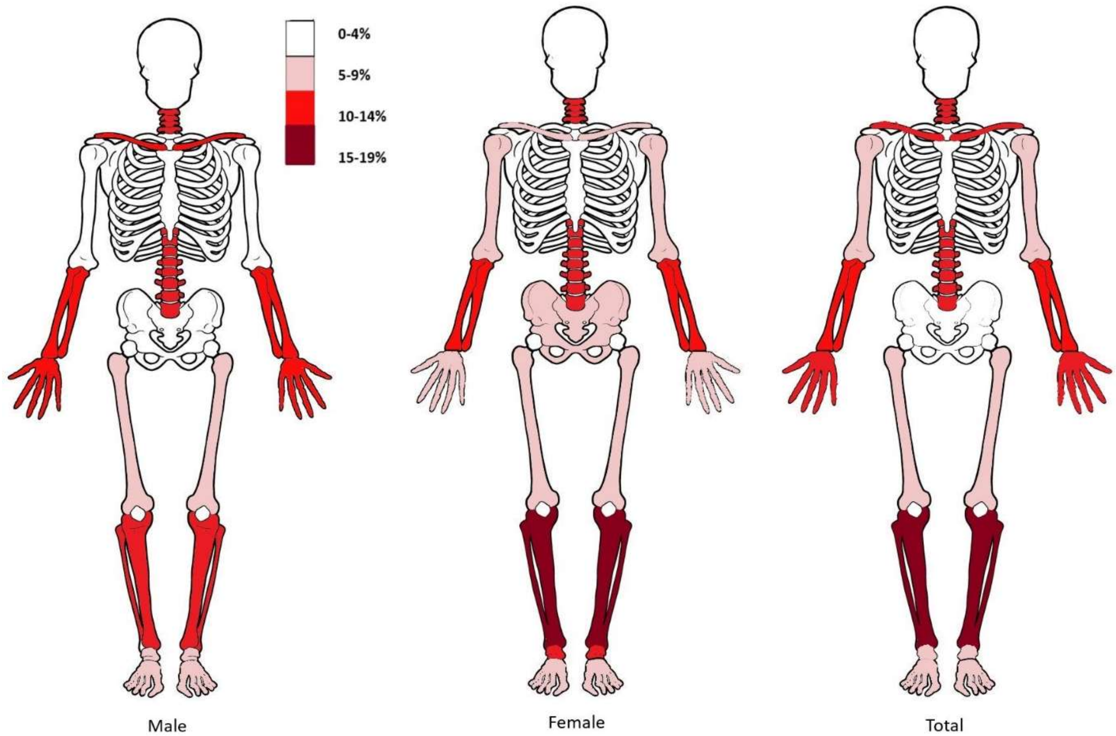


Figure 3. Distribution of the patients age and gender in all crashes.

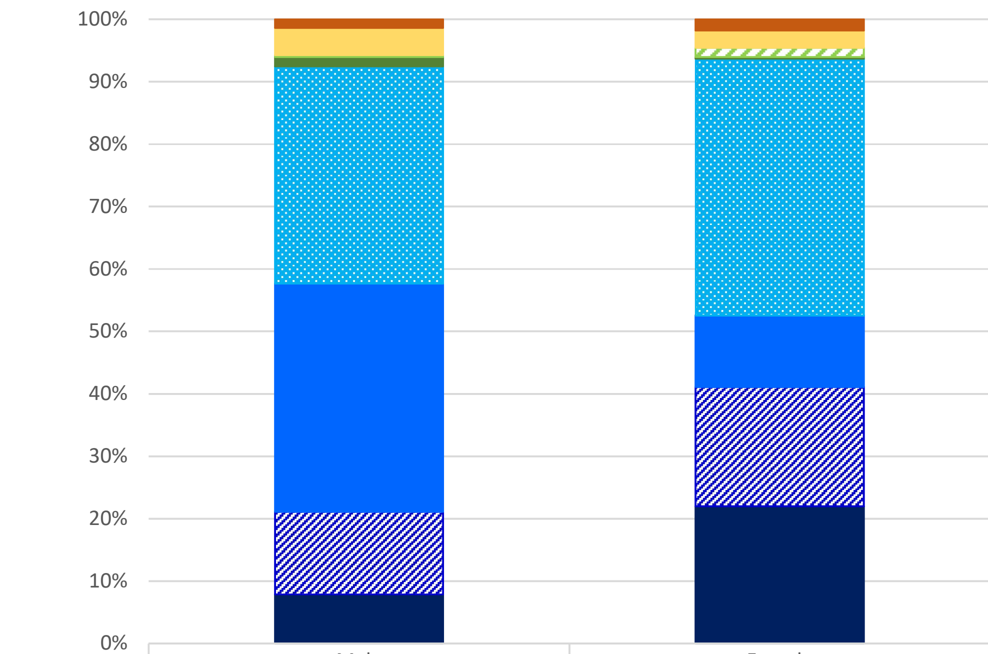
The main body regions fractured were the tibia/fibula (14.7%) and the vertebra (12.8%). The distribution of the fractured body regions by gender is shown in Figure 4. According to χ^2 test of independence, the relation between fractured body region and gender was significant ($p<0.0005$), with the main observable differences being fractures at the clavicle and pelvis.



	Clavicle	Scapular	Humerus	Radius/ ulna	Hand	Pelvis	Acetabulum	Femur	Patella	Tibia/fibular	Ankle	Foot	Vertebra
Male	150	40	56	135	129	39	38	67	16	166	87	103	157
Female	45	10	47	86	62	44	13	33	3	105	69	61	78
Total	195	50	103	221	191	83	51	100	19	271	156	164	235

Figure 4. Percentage of fractures within the different body regions for persons involved in all matched crashes.

Figure 5 shows the road user type involved in the crash resulting in a fracture by gender. Car occupants were most frequently involved (37%), followed by motorcyclists (27.6%) and bicyclists (15.4%). There was a significant association between transport mode and gender ($p<0.0005$). Overall, there was a larger number of female pedestrians with a fracture than male; however, there was a much larger number of male motorcyclists fractured than there were females. Overall, the 21-25-year-old age group was the largest (11.7%), followed by 16-20-year-olds (9.9%), see Figure 6.



	Male	Female
Unspecified	16	12
Other	53	18
Bus	3	10
Truck	18	2
Car	417	273
Motorcyclist	438	76
Cyclist	159	127
Pedestrian	94	146

Figure 5. Road user type injured in all crashes by gender.

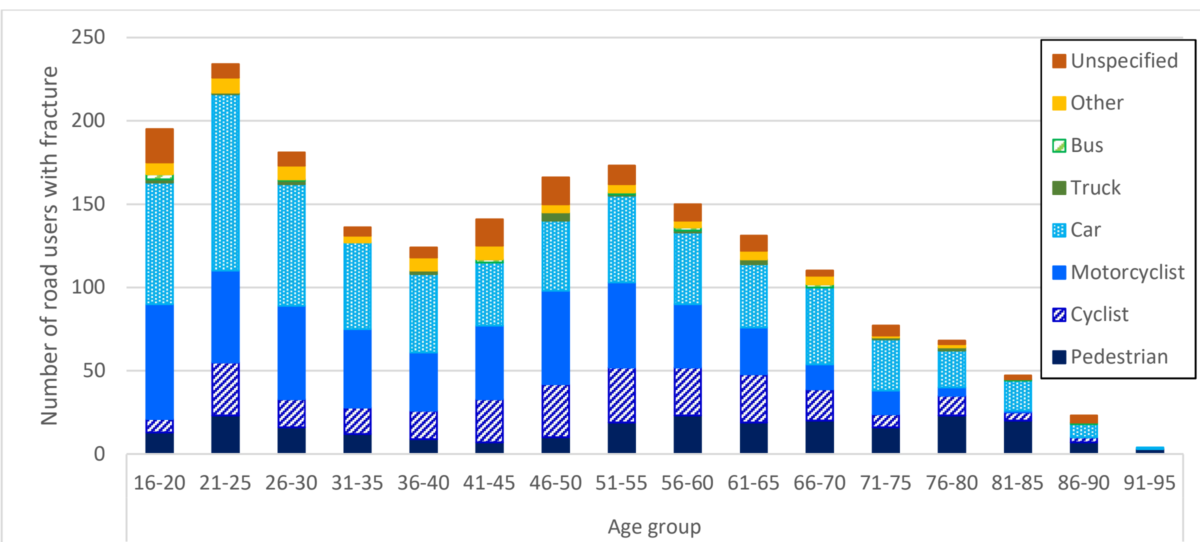
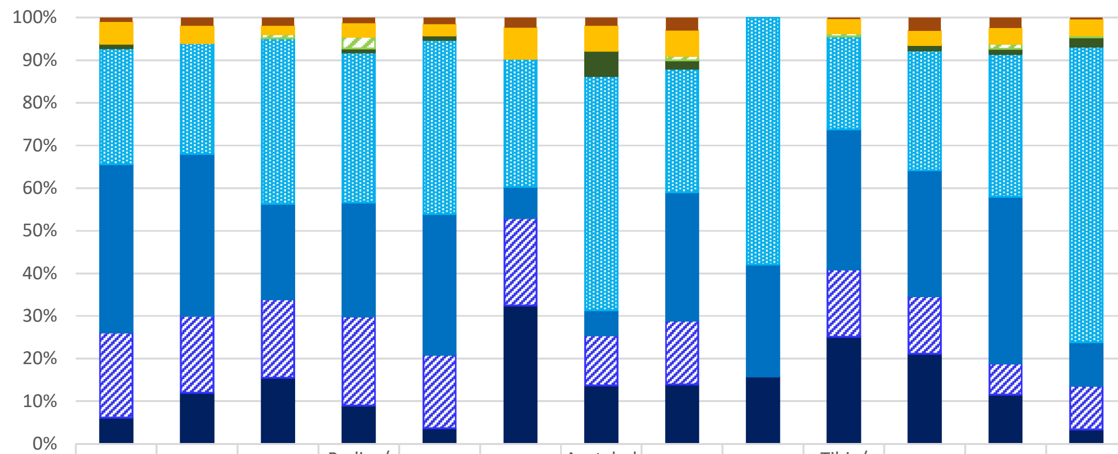


Figure 6. Road user type injured in all crashes by age.

The proportion of fractures on the different body regions by transport mode can be seen in Figure 7. Notably, 69.4% of all vertebral fractures were to car occupants, 39% of all foot fractures happened to a motorcycle rider. Additionally, 54.9% of acetabulum fractures were to car occupants and 32.5% for pelvic fractures were to pedestrians.



	Clavicle	Scapular	Humerus	Radius/ ulna	Hand	Pelvis	Acetabul um	Femur	Patella	Tibia/ Fibula	Ankle	Foot	Vertebra
Unspecified	2	1	2	3	3	2	1	3	0	1	5	4	1
Other	10	2	2	7	5	6	3	6	0	9	5	6	9
Bus	0	0	1	6	0	0	0	1	0	2	0	2	1
Truck	2	0	0	2	2	0	3	2	0	0	2	2	5
Car	53	13	40	78	78	25	28	29	11	59	44	55	163
Motorcyclist	77	19	23	59	63	6	3	30	5	89	46	64	24
Cyclist	39	9	19	46	33	17	6	15	0	43	21	12	24
Pedestrian	12	6	16	20	7	27	7	14	3	68	33	19	8

Figure 7. Road user type injured in all crashes by fractured body region.

Fractures occurred most frequently in the summer months (June – August), see Figure 8. Contrarily, 75% of the fractures occurring while on a train/tram were in March and 50% of fractures which occurred while on a bus were between January and March, with a further 38.5% occurring in December. However, the overall numbers in these groups were very small.

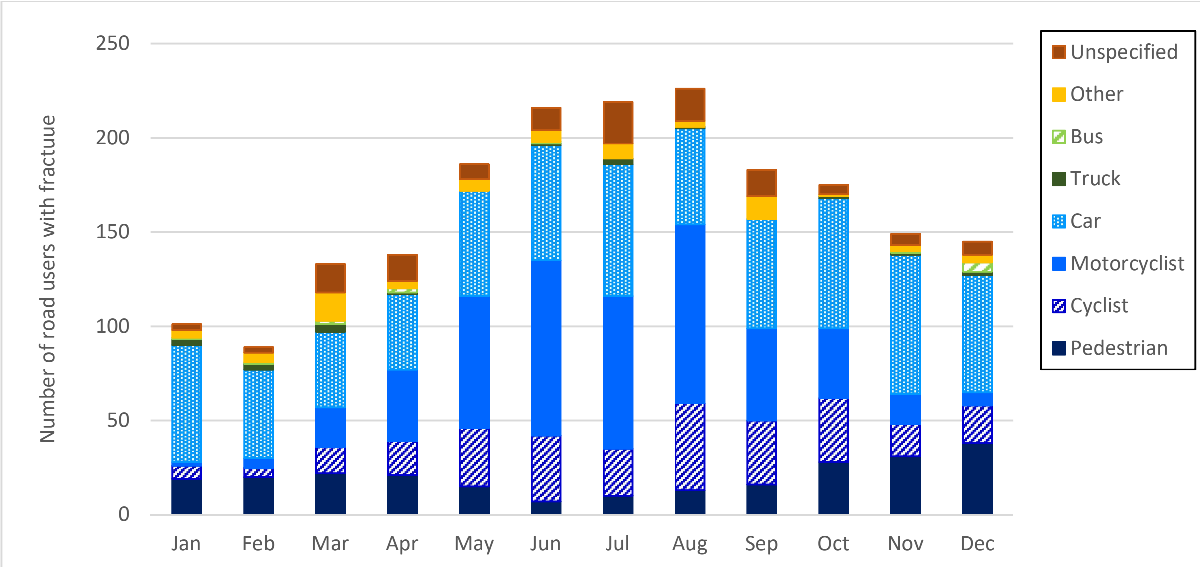


Figure 8. Road user type injured in all crashes by month.

Cyclists

There was a total of 284 cases of cyclists who suffered a fracture who were included for analysis, with one cyclist being included twice due to being involved in two separate cases. Table 2 shows the year and month of fracture. The warmer months (May to October) had a higher proportion of fractured riders, and the most common month was August (15.8%). Västra Götalands county involved the largest number of riders (21.8%), see Figure 9.

Table 2. Distribution of cyclists with a fracture by year and month.

Variable	n(%)
Year	
2014	82 (28.9)
2015	94 (33.1)
2016	108 (38)
Month	
January	7 (2.5)
February	5 (1.8)
March	13 (4.6)
April	17 (6)
May	32 (11.3)
June	36 (12.7)
July	26 (9.2)
August	45 (15.8)
September	34 (12)
October	32 (11.3)
November	18 (6.3)
December	19 (6.7)

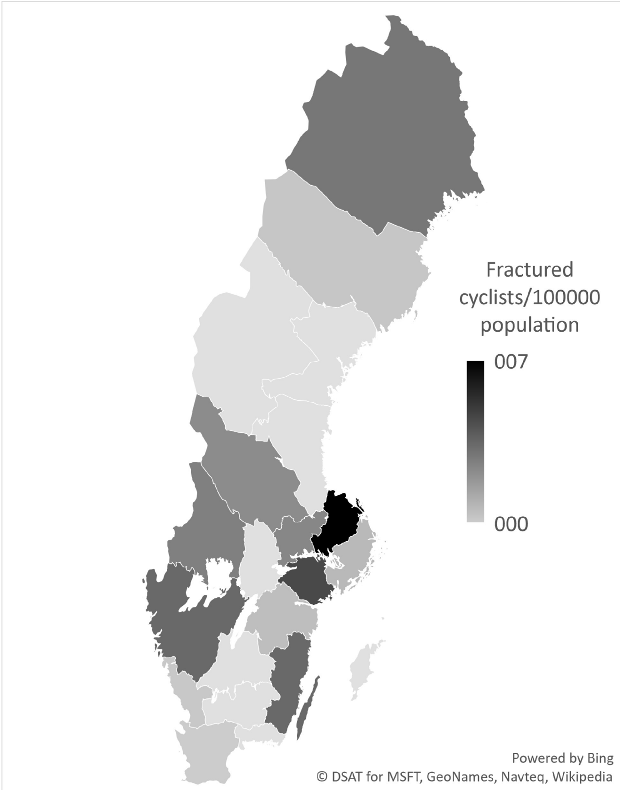


Figure 9. Map of the counties where the cyclists' fractures occurred, normalised by the total population in each county.

Fractured riders were predominantly males (53.9%). The average age of all fractured cyclists was 48.75 years, ranging from 16 to 87 years. Table 3 displays the proportion of cyclists within the different age groups by gender. Those aged 50+ years accounted for the largest proportion of both males (21.6%) and females (24.4%). There was a smaller proportion of females than males in the youngest three age groups.

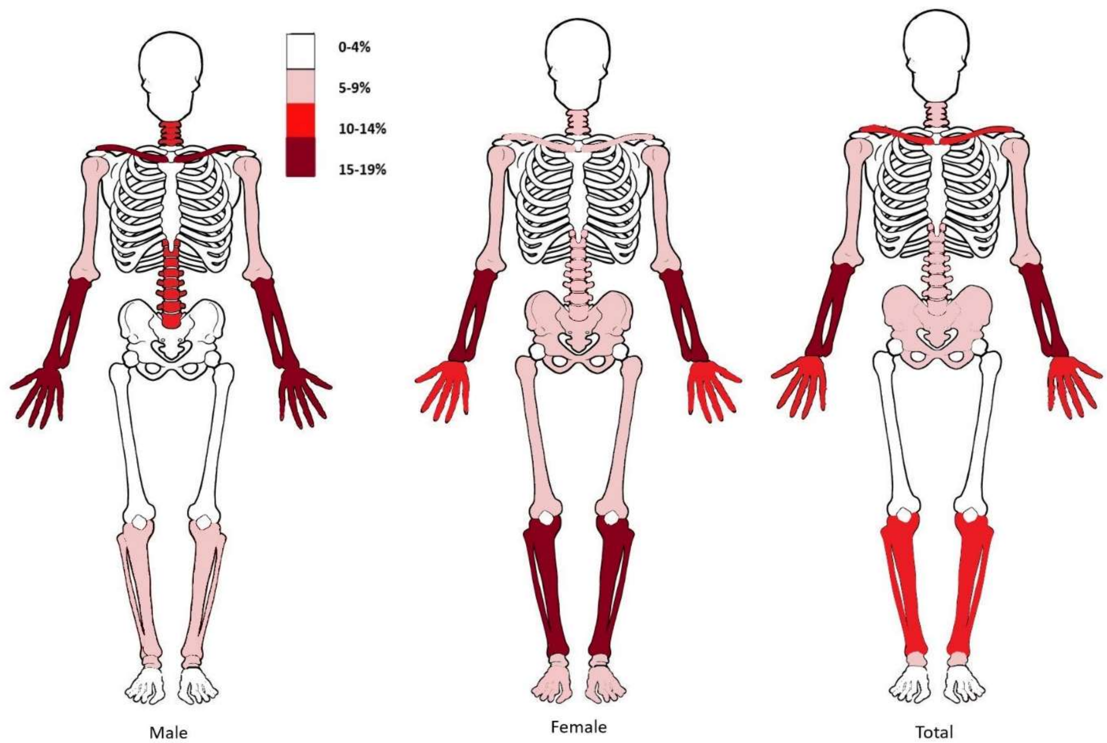
Table 3. The age of cyclist by gender.

	Male n(%)	Female n(%)	Total n(%)	95%CI for total n(%)
Age (n=284)				
16-29	31 (20.3)	22 (16.8)	53 (18.7)	40-66 (14.1-23.1)
30-49	57 (37.3)	35 (26.7)	92 (32.4)	76-107 (26.9-37.8)
50+	65 (42.5)	74 (56.5)	139 (48.9)	122-156 (43.1-54.8)

Among the 284 cyclists, there were 327 fractures. These fractures were predominantly to the radius/ulna (17.4%), clavicle (14.1%) and tibia/fibula (13.1%). Fractures to the hand (12.8%), vertebra (8%) and humerus (7%) also occurred frequently.

χ^2 test of independence found significant association between gender and location of fracture ($p=0.004$). Females mostly suffered a higher percentage of fractures than males to the lower limbs including the pelvis, acetabulum, femur, tibia ankle and feet (see Figure 10).

Males tended to have a higher percentage of fractures to the upper limbs, including the clavicle, scapular, radius/ulna and hand. Males also suffered a higher percentage of fractures to the vertebra.



	Clavicle	Scapular	Humerus	Radius/ ulna	Hand	Pelvis	Acetabulum	Femur	Patella	Tibia/fibular	Ankle	Foot	Vertebra
Male	30	5	7	28	20	21	3	4	1	17	10	6	1
Female	11	3	11	24	12	12	1	10	0	23	11	7	6
Total	41	8	18	52	32	33	4	14	1	40	21	13	7

Figure 10. Percentage of fractures in each body region of the cyclist.

The results in Figure 11 suggest a difference of injury location by age group. However, the difference was not statistically significant according to a chi-square test of independence (p=0.27). Initial analysis did not meet expected cell counts, so small numbers were grouped and reanalysed, but the repeated tests still did not give significant differences.

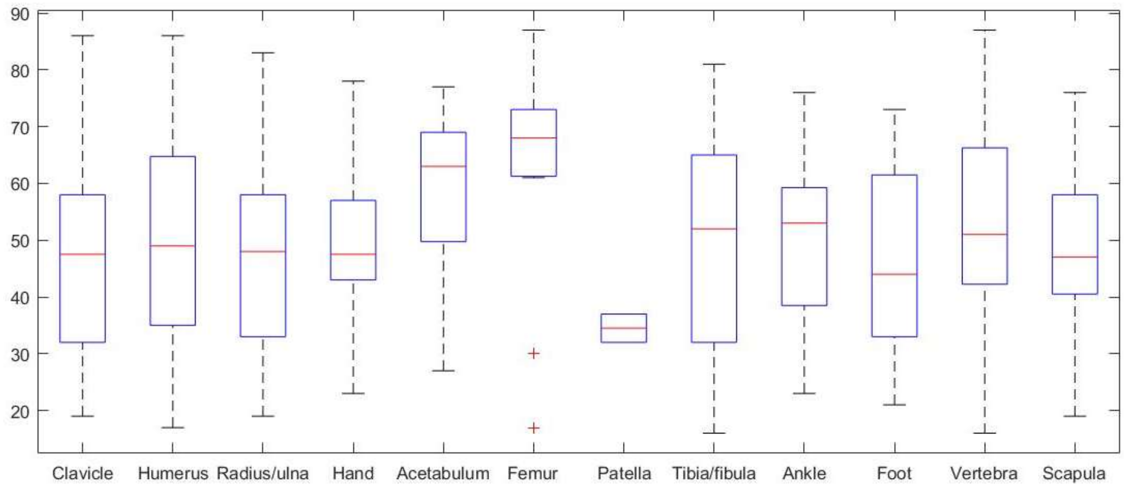


Figure 11. Mean age for the fractured body regions of the cyclist.

Out of the 327 injuries, 162 (49.5%) were coded as a 'high energy injury' and 38.5% were 'low energy', with 12% unknown. Fractures to the acetabulum (100%), pelvis (84.2%), vertebra (75%) and tibia (70.3%) were most frequently high energy fractures, whereas fractures to the upper extremities, including radius/ulna (58.8%) and humerus (63.2%) were more frequently low energy fractures (Figure 12). A test of independence found that body region and the energy of the impact were significantly associated (p=0.006).

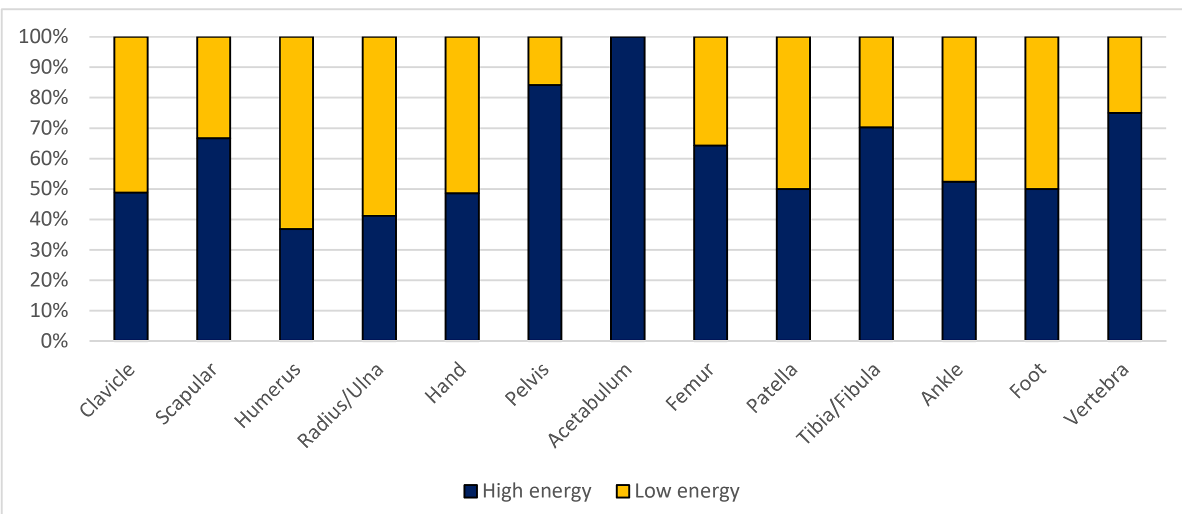


Figure 12. Energy of the fracture by fractured body region for the cyclist.

Males contributed to 51.9% of the high energy injuries and 54.8% of the low energy injuries, and there was no significant relationship observed between gender and the energy of the injury.

The most common impact partner to the cyclists was a car (58.5%). Single bicycle crashes (no impact partner) were also frequent (21.8%). Logistic regression found that single bicycle incidents (OR=0.165) and collisions with another bicycle (OR=0.148) were significantly less likely to result in a high energy fracture than a collision with a car (Table 4).

Table 4. Results of the binary logistic regression examining the association between the impacted vehicle and the energy of the fracture.

	High energy n(%)	Low energy n(%)	p-value	OR	95% CI
Impact partner					
None (Single bicycle incident)	16 (10.1)	43 (35.8)	<0.0005*	0.165	0.077-0.356
Pedestrian	5 (3.2)	4 (3.3)	0.19	0.554	0.23-1.335
Motorcycle/moped	5 (3.2)	2 (1.7)	0.91	1.109	0.206-5.959
Heavy vehicle	12 (7.6)	5 (4.2)	0.94	1.064	0.24-4.716
Bicycle	5 (3.2)	15 (12.5)	0.001*	0.148	0.049-0.442
Car	115 (72.8)	51 (42.5)	reference	-	-

* significant at p<0.05

Police reports were available in 200 of the 284 fractured cyclist cases. Results from these police reports found that, disregarding unknown values, collisions with a car frequently occurred in an urban environment (88.9%) and on an urban street (62.6%), most frequently at an intersection (47.7%), see Table 5. Only one collision occurred on a motorway. The weather was mostly dry (84%), with a dry road (71.6%) and under daylight conditions (77.7%).

Table 5. Environmental factors for the cyclist crashes

Variable	Proportion n(%)
Environment	
Urban	159 (88.9)
Rural	20 (11.1)
Unknown	105
Place	
Road intersection	94 (47.7)
Road	59 (29.9)
Footpath	1 (0.5)
Combined pedestrian and cycle path	25 (12.7)
Roundabout	18 (9.1)
Other/unknown	87
Road type	
Motorway/freeway	1 (0.6)
Major or minor arterial	2 (1.2)
Other public road	52 (30.4)
Urban Street	107 (62.6)
Other road	9 (5.3)
Unknown	113
Weather	
Dry	142 (84)
Fog	3 (1.8)
Rain	24 (16.9)
Unknown	115
Light conditions	

Daylight	139 (77.7)
Dark	26 (14.5)
Dawn/dusk	14 (7.8)
Unknown	105
Road state	
Dry	121 (71.6)
Wet/damp	45 (26.6)
Thick ice/packed snow	1 (0.6)
Thin ice	1 (0.6)
Loose snow/slush	1 (0.6)
Unknown	115

Discussion

The first aim of this investigation was to match SFR with STRADA and to examine this matched dataset. This investigation found that the number of cases which were able to be matched were low. From a total number of 12,371 cases of fractured people involved in road crashes, only 1960 were able to be matched with the STRADA dataset, and this consisted of 284 cyclists. The combined datasets provided a high number of variables, with both details about the crash, including road conditions and weather conditions, as well as detailed information about the fracture, including energy of the fracture, and long-term follow-up information. However, the long-term follow up information was not available for our use at this stage but would be of great use in the future.

The matched dataset was used to look at the overall pattern of fractured road users. Cars were the vehicle type which were most frequently involved in crashes resulting in fractures (37%), followed by motorcycles (27.6%) and bicycles (15.4%). Fractured cyclists were typically younger than bus, train or tram riders, but older on average than motorcyclists.

Additionally, there were gender differences. Overall, there was a larger number of female pedestrians with a fracture than male; however, there was a much larger number of males who were fractured when riding a motorcycle. This may be a result of exposure, as shown in a study in Australia, where the population data reported 88% males and correspondingly, 94% of the injured sample were males.[9] In Sweden, males have also been recorded to travel a higher number of kilometres per day than females, and those males aged 55-64 years rode the longest every day (7km per day).[10] Cyclists fracture locations differed to all other road users as all other road users suffered the highest proportion of fractures to the bones in the lower leg (14.7%), whereas cyclists were more frequently injured in the lower arm (17.4%).

The different kinematics, ages and genders typically seen in drivers of different vehicle types may explain the difference in the fracture pattern. Cars were the most frequent impact partner resulting in a fracture to a cyclist in this investigation. Single cyclist crashes were also frequent. The fracture energy was different in different crash scenarios, with single bicycle incidents and collisions with another bicycle were significantly less likely to result in a high energy fracture than a collision with a car. This is indicative of different kinematics within different impact scenarios, with single bicycle incidents resulting in the rider sliding along the roadway; whereas impacts with another car or other vehicle result in the rider being thrown in to the air. As such, protection should be designed accordingly.

There is a high number of single bicycle crashes in the STRADA dataset, with single bicycle crashes comprising 69% of all crashes between 2012-2014,[11] while cars were the most frequent impact partner in SFR, indicating that perhaps impacts with another vehicle tend to lead to fractures more often than those single bicycle crashes. It is worth noting that there have been under-reporting problems identified within the police reporting of STRADA, specifically with regards to single cyclist crashes.[12] Additionally, until May 2014, within the study time period, the police reporting system for STRADA had some issues, so approximately 20% of police-reported cases in the first half of 2014 were missing in the database.[13]

Additionally, within cyclists, the injury location varied based on gender. Females mostly suffered a higher percentage of fractures than males to the lower limbs including the pelvis, acetabulum, femur, tibia ankle and feet. Males tended to have a higher percentage of fractures to the upper limbs, including the clavicle, scapular, radius/ulna and hand. Males also suffered a higher percentage of fractures to the vertebra. This could be associated with intrinsic differences in males and females body types such as height and weight differences as well as potentially indicating that there could be different kinematics between female and male riders following a collision as a result of different body types, or that males and females are involved in different types of collisions. The results showed a significant correlation between high-energy and low-energy crashes and collision partner, which would explain different injuries in different types of collisions. Unfortunately, for this study, data was not available on patient details such as height and weight, so it was not possible to observe differences in gender based on height and weight and injury outcome. Collision types and falling patterns should be explored further, particularly in relation to gender differences. There may be a need for improved mitigation strategies, which should address both gender-related effects and other differences associated with gender.

Protection should also be designed for different crash scenarios, with high and low energy fractures occurring in crashes with different impact partners and resulting in fractures to different parts of the body. In cyclists, therefore, there is also a need to examine closely the injury kinematics for fractures to different body regions so that body region and cyclist specific protection can be created. Additionally, while independence of age group and injury location could not be rejected by the chi-square test, differences in the corresponding percentages suggest that a significant dependence could possibly be found in larger samples.

A study by Stigson et al.[14] examined kinematics of fractures to the clavicle, which were found to be the most frequently occurring injury. Injury to the shoulder was a result of a direct blow to the shoulder in 90% of cases and falling onto an outstretched arm in only 1 case. Similarly to Stigson et al.,[14] this study found that the upper limbs were the most frequently fractured, involving mostly the radius, ulna and clavicle. However, high energy fractures were most frequently to pelvis, vertebra and lower limbs. Low energy fractures occurred more frequently to the radius and ulna. It is therefore necessary to focus on protection for the upper limbs as well as the pelvis, vertebra and lower limbs, with different protection to suit the different impact scenarios, so that both most frequently occurring injuries and highest severity injuries can be prevented.

Motorcycle protection focuses on garments with fitted energy absorption, or 'impact protectors', at certain regions in motorcycle specific clothing and this could be an option for cyclists. However, while impact protection has been shown to attenuate sufficient energy to prevent fractures,[15] in the real world, it was shown to prevent injury overall but not specifically fractures.[16] More recent advancements, such as airbag jackets, may provide further protection.

Cyclists were more frequently fractured in the summer months, which matched with previous reports on cyclist flow in Gothenburg, where cyclists flow was greater in the warmer months, with the exception of July when the Swedish population is on holidays.[11] These results are also in line with previous study on tibia fractures caused by traffic (Wennergren et al. 2018). This indicates that the increase in cyclists suffering fractures as a result of a crash in summer is likely due to increased exposure. No cyclists reported having a crash in the snow; however, one was riding on a snowy road. This may additionally indicate that there a fewer cyclists riding in bad weather.

Conclusion

The percentage of matched data was low, with only 15.8% of SFR being matched with STRADA. However, the matching process allowed for analysis of many factors including details regarding the crash and subsequent injuries. Cyclists who were fractured in a road crash mostly involved males with an average age of 49 years. There were differences found in injuries based on age, gender and impact partner, indicating that protection of different fractures needs to be designed based on the different injury scenarios. There is a need to examine more closely the injury mechanisms associated with different fractures so that appropriate protective devices can be designed based on the different injury mechanisms.

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