



Cycling Related Injuries: A Tour De Trauma

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Introduction

- Health benefits of cycling?
- Cycling in Ireland
- Injury Patterns in cyclists
- Spinal injuries in cyclists
- Predicting Injury Sites / Events
- Systemic changes

Benefits of Cycling Holland



(0.8–40 days lost)



(5–9 days lost)



(3–14 months gained)

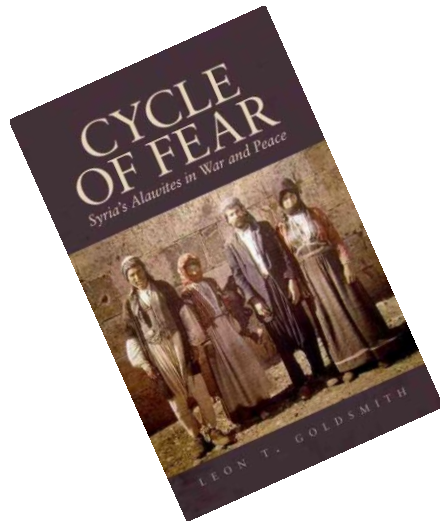


reduction in air pollution and greenhouse gas emissions and traffic accidents.



Barriers to Cycling Canada

- Risk:
 - Real
 - Perceived
- ED Presentations
- 34% MVA collisions
- 14% were a result of avoidance of a motor vehicle
- Risk present on multi-use paths: falls / other collisions, away from motor vehicles





Popularity

- Bike to Work Tax Indemnity Scheme 2009
- CSO 95,000 bikes sold last year
 - vs 91,732 new vehicles
- ‘Bicycle economy’
 - €37.37m in 2004
 - €49.14m in 2012





Competitive Cycling

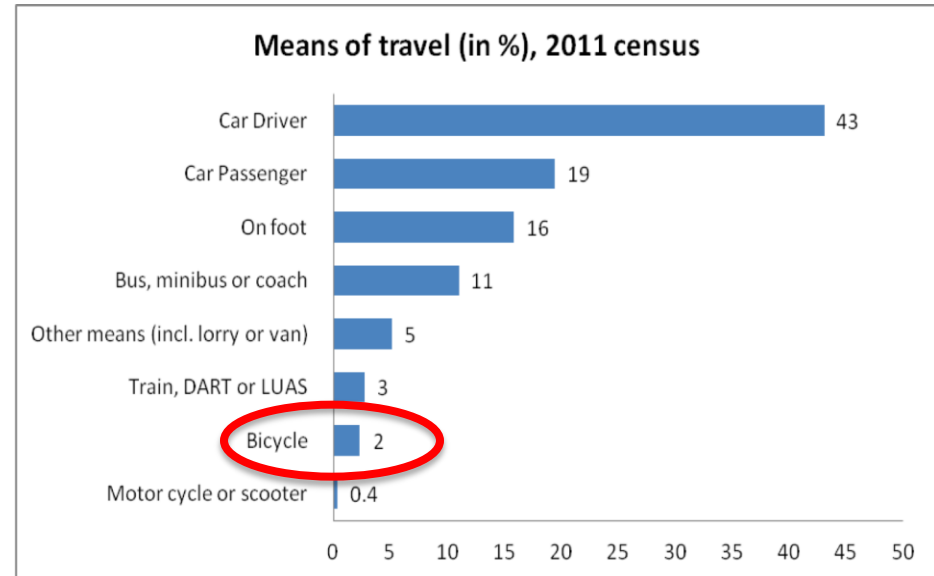
- >20,000 people participated in a triathlon in 2011
- Cycle Ireland had 18,000 members last year



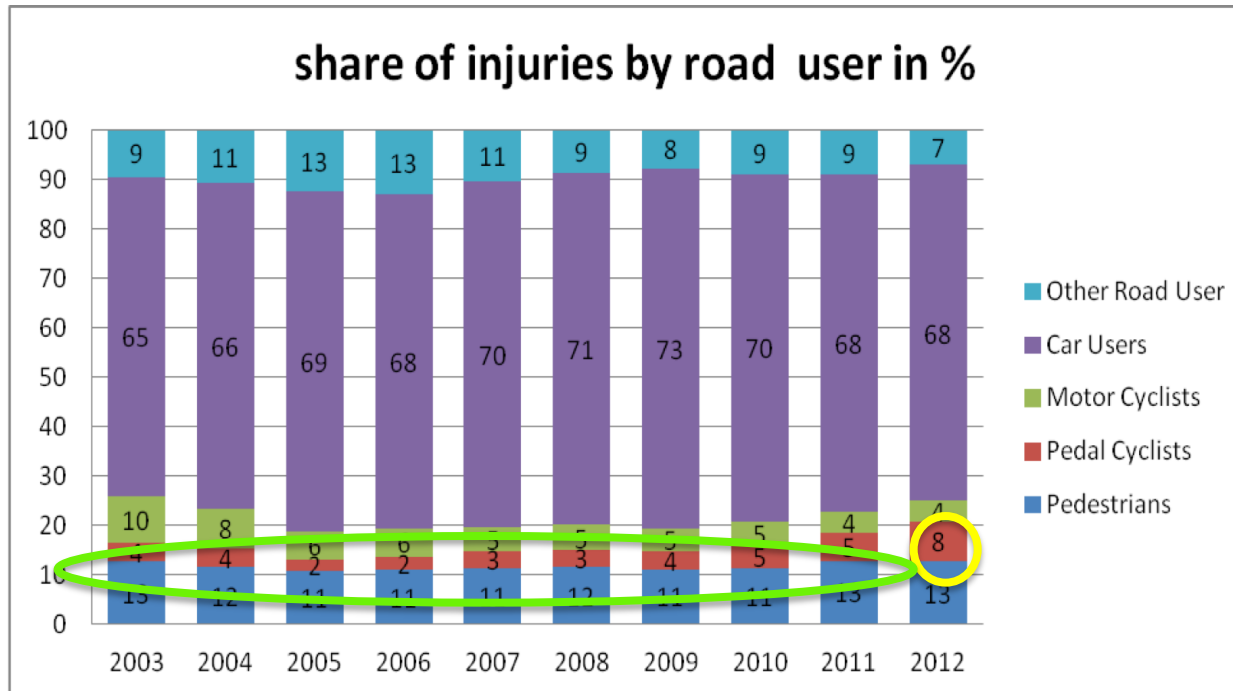


2006 – 2011 CSO

- 61,177 regular cyclists (2% road users)
- 9.6% **↑** commuting from 36,306 to 39,803
- 21,374 people cycled to school / college.
- 75% Male



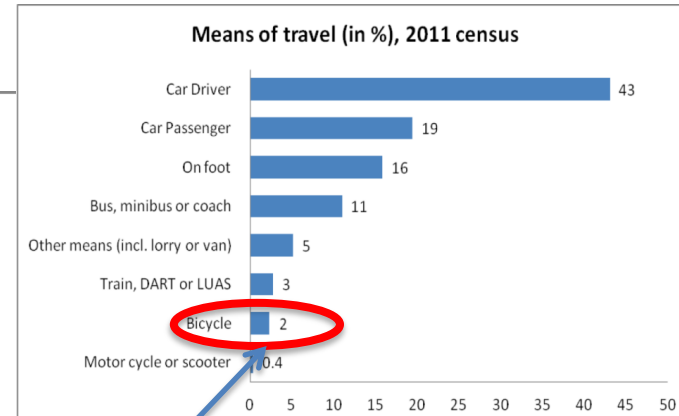
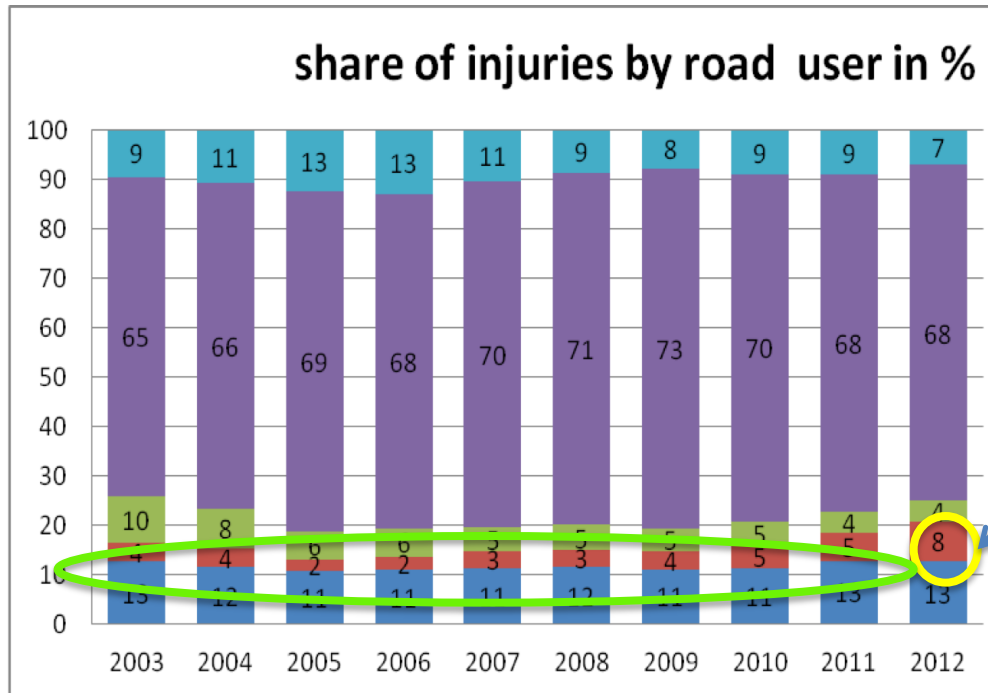
RSA



2003 - 2012 cyclists accounted for 2-5% of injured road users
2012 increase from 395 to 630 (59% increase)
From 2% to 8% of total



RSA



Car Users
Motor Cyclists
Pedal Cyclists
Pedestrians

X4 mismatch
Road users 2%
Injured 8%

2003 - 2012 cyclists accounted for 2-5% of injured road users
2012 increase from 395 to 630 (59% increase)
From 2% to 8% of total

Predicting Injury Patterns?



Cycling-Specific Injury Patterns

Variables

- Personal Protection
- Speed of collision
- Impact surface
- Helmet / Clothing
- Variable
- Sliding / shear forces
- **Direct impact**
- **Motor vehicle crashes**
- **Roll over injuries**



Age & SEG Canada

Davison et al. International Journal for Equity in Health 2013, 12:48

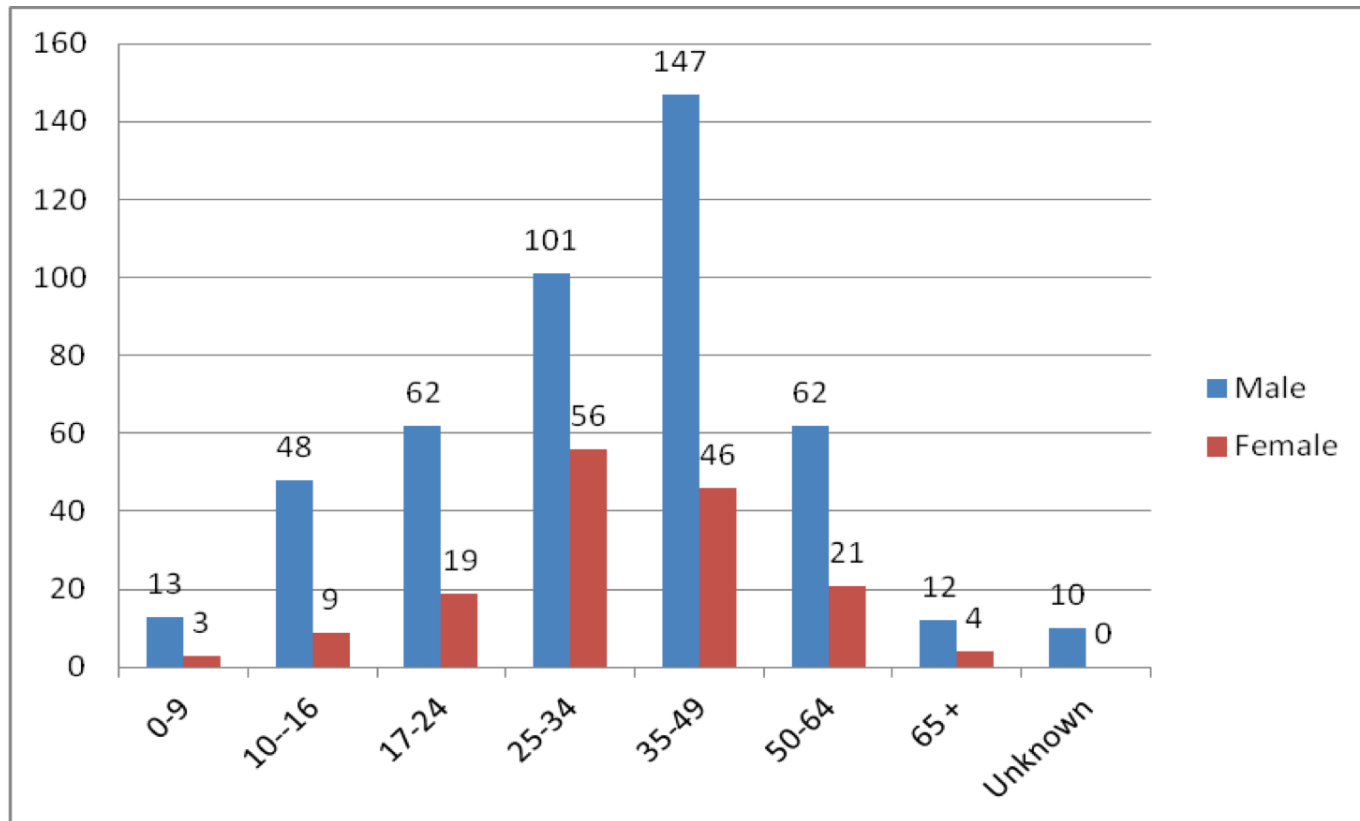
Socio-demographic characteristic	Crude relative risk				Adjusted relative risk	
	No.	% Injured	RR [3]	95% CI	RR [4]	95% CI
Sex						
Female	310	3.4	1.00		1.00	
Male	671	6.9	2.13	[1.85-2.46]	2.02	[1.78-2.30]
Age						
≥ 15 yrs	429	6.4	1.00		1.00	
13-14 yrs	362	4.9	0.77	[0.66-0.90]	0.77	[0.66-0.90]
< 13 yrs	188	4.0	0.62	[0.53-0.78]	0.62	[0.51-0.76]
Socioeconomic Status						
Above Average	542	5.1	1.00			
Average	314	5.2	1.01	[0.88-1.16]		
Below Average	84	5.2	0.99	[0.79-1.25]		
Urban-rural Geographic Location						
Large urban	307	5.1	1.00			
Medium urban	189	4.7	1.01	[0.79-1.30]		
Small Town	442	5.5	1.10	[0.89-1.37]		
Rural	42	5.9	1.21	[0.79-1.85]		
Years in Canada						
Born in Canada	654	4.9	1.00		1.00	
Immigrant > 5 yrs	267	5.9	1.23	[1.06-1.42]	1.14	[0.98-1.32]
Immigrant ≤ 5 yrs	50	6.9	1.43	[1.07-1.93]	1.35	[1.00-1.82]



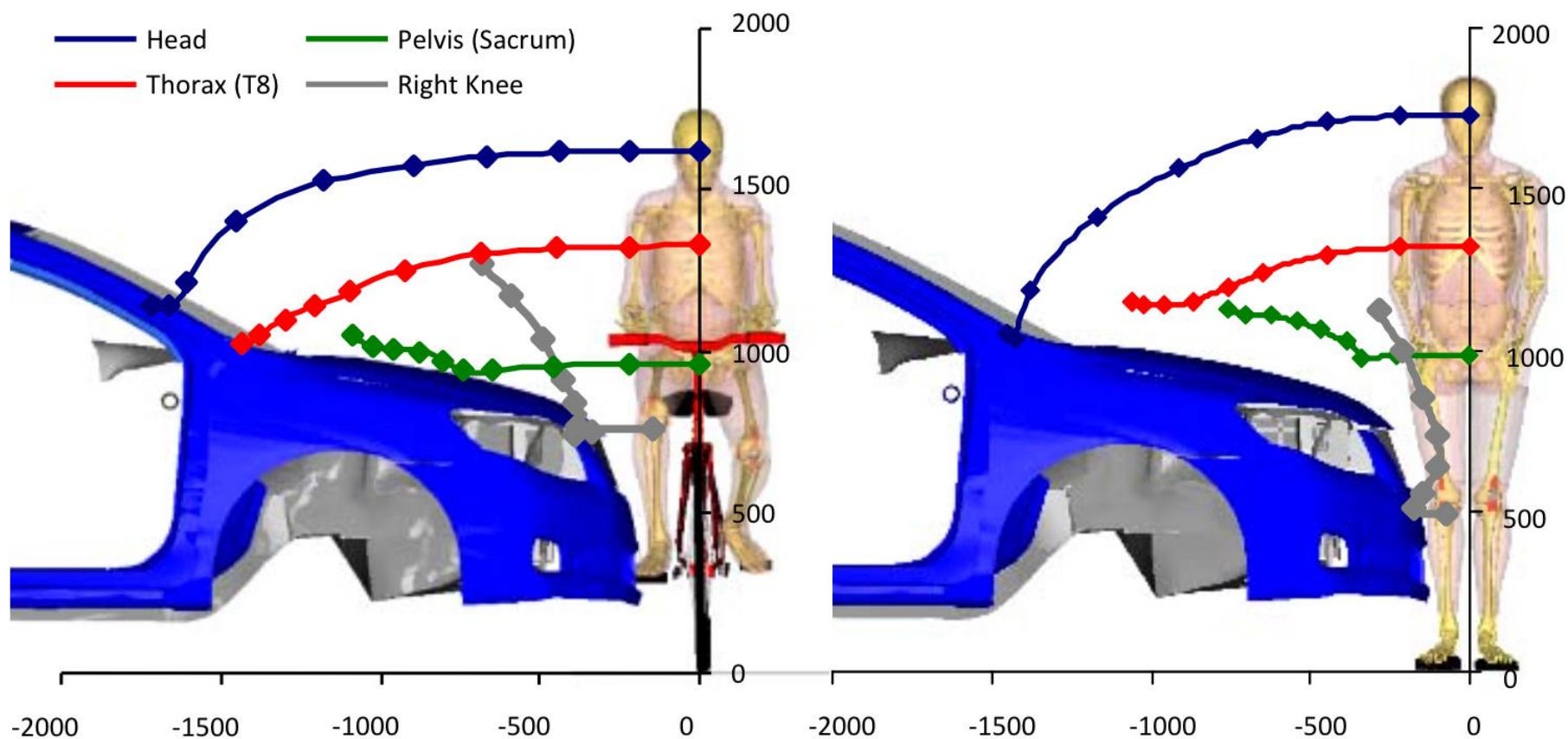


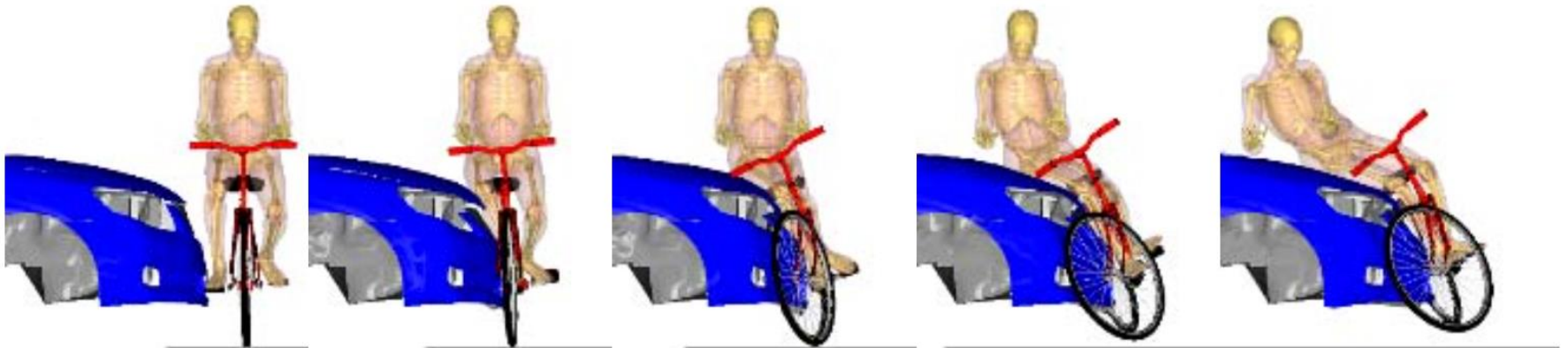
Ireland

2012 cyclist injuries by age & gender



Comparison of Cyclist vs Pedestrian





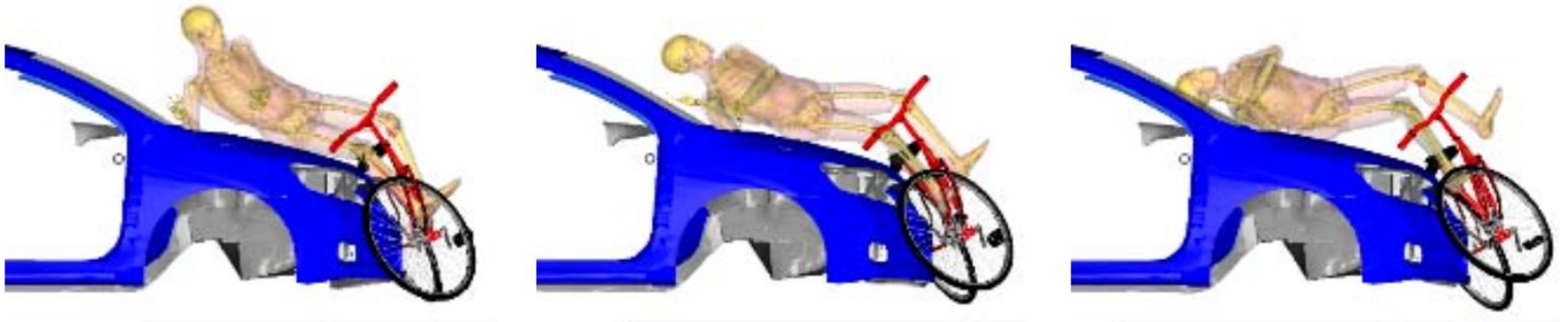
0 ms

20 ms

40 ms

60 ms

80 ms



100 ms

120 ms

140 ms



Injury Patterns Canada

- 11772 severely injured pts (ISS>17)
- 2.2% (307) cyclists
- 7% mortality
- Street: Motor vehicle accidents
- Mountain: rider error

- Head 67%
- Spinal fracture 46%
- Spinal cord injury 8%
- Extremities 38%
- Chest 34%
- Face 26%
- Abdomen 10%
- 33% reqd surgery
- 10% orthopaedic
- 8% spine
- 7% craniotomy
- 5% facial
- 3% general surgery



Injury Pattern Germany

- 153 polytrauma pts
 - 21% (32) were cyclists
 - Mean age 42yr, M:F 1:1
 - **30/32 of pts suffered head injuries**
 - **30/32 without a helmet**
-
- **88% leading injury was to the head**
 - **Median GCS 8**



Strohm et al. Unfallchirurg. 2005 Dec;108(12):1022-4, 1026-8.



Age & Helmet Wear Canada

Davison et al. International Journal for Equity in Health 2013, 12:48

Sub-group	Never wears a helmet, (count and row %)	Inconsistently wears a helmet (count and row %)	Always wears a helmet, (count and row %)
Grade level:			
< 8 (n= 8178)	2139 (26.2)	2852 (34.9)	3187 (39.0)
8-9 (n= 7708)	3794 (49.2)	2462 (32.0)	1452 (18.8)
≥ 10 (n= 3522)	2332 (66.2)	809 (23.0)	381 (10.8)



Teen factor?
Helmet hair?



Age & Helmet Wear Ireland








Helmet Wear: Overall	8/9yo	12/13yo	Girls	Boys
49.6%	62%	33%	61%	39%

MB Quirke et al



Head Injuries & Helmet Wear (HW)

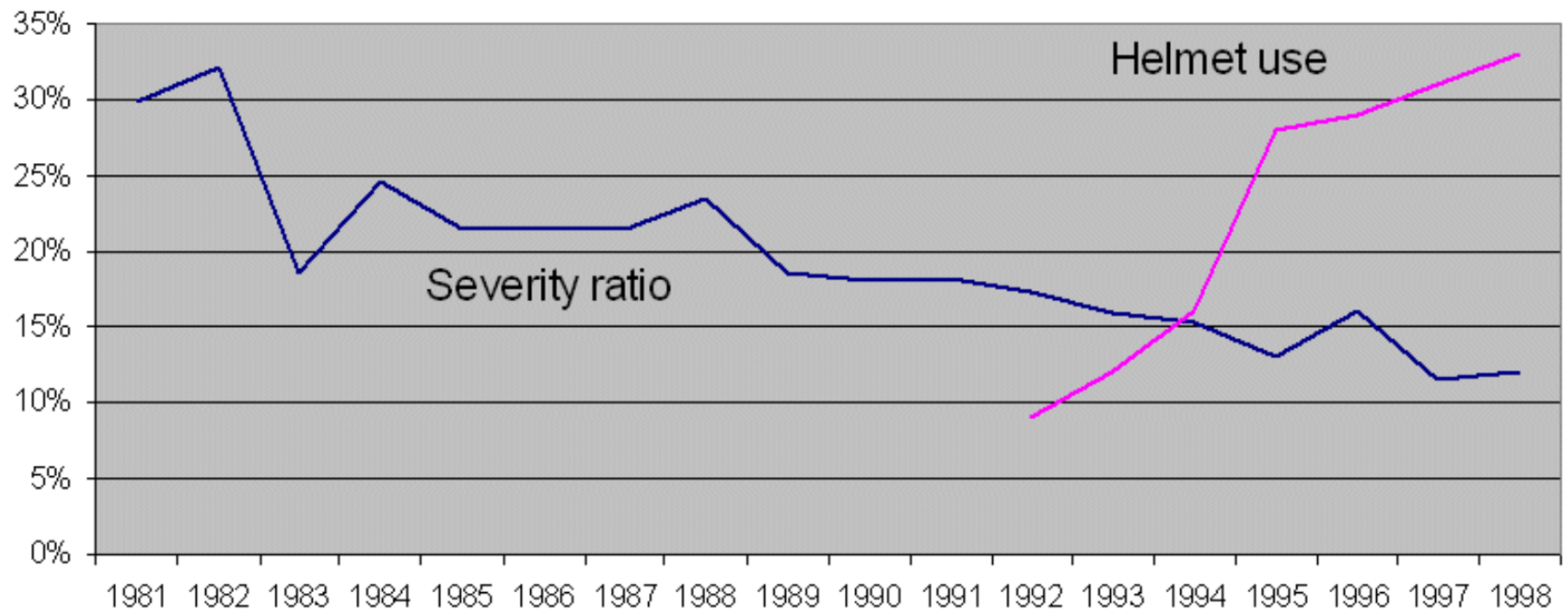
Overall HW	Paediatric HW	Head Injury	Head Injury	Head Injury	Head Injury	Head Injury	Head Injury
				MVA	Non MVA		
		Priv	Non HW			Protective Factor	MVA Relative Risk
11%	16%	4%	11%	18%	7%	3.25	2.95

1040 pts presenting to ED in Addenbrookes, Cambridge, UK

Maimaris et al. BMJ1994;308:1537-40

Cambridge UK

Cambridge: Cyclist injury severity ratio and helmet use



Bicycle Helmet Research Foundation

<http://www.cyclehelmets.org/1144.html>



Cochrane
Library

Trusted evidence.
Informed decisions.
Better health.



Head injury

- 1/3 of ED visits
- 2/3 of hospital admissions
- $\frac{3}{4}$ of deaths

Helmets

- Risk of head, brain and severe brain injury ↓ 63 - 88% for all ages of bicyclists
- Equal levels of protection for crashes involving motor vehicles (69%) and crashes from all other causes (68%)
- Injuries to the upper and mid facial areas are reduced 65%.



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National Spinal Injuries Unit 1991-2014







Mater 1993-2003

Sport	No. (%)	Gender	Mean age (range)	Length of stay	Pattern of injury	Mechanism of injury	Neurology	Surgery (%)
Equestrian	82 (41.8)	42 males 40 females	35 (15–72) years	9.5 (1–82) days	29% thoracolumbar jxn 25% cervical 22% thoracic 21% lumbar 3% cervicothoracic	Fall/thrown from horse Jumping most common activity	23–17% complete	29
Rugby	32 (16.3)	32 male	21 (14–53) years	8.1 (3–29) days	C5/6 #-subluxation	Hyperflexion > hyperextension Loose play > scrums	50–56% complete	35
Diving	30 (15.3)	28 males 2 female	25 (16–40) years	9 (1–21) days	90% cervical spine (C6 most common level) 10% lumbar	Combined axial loading ± hyperflexion following diving/sliding head first into shallow water Lumbar # if dived feet first	60–39% complete	43
Gaelic football	16 (8.1)	16 males	25 (15–25) years	5 (1–13) days	Cervical spine (C5 most common level)	Hyperflexion > hyperextension following tackles + collisions on pitch	25–6% complete	6
Hurling	3 (1.5)	2 males 1 female	26 (16–34) years	8.3 (1–15) days	Cervical spine (C6/7)	Hyperflexion injury to following tackles + falls	66–50% complete	33
Rock climbing	5 (3)	4 males 1 female	28 (22–45) years	26.4 (5–84) days	Thoracolumbar junction 60% > 1 vertebral level affected	Fall from height	40–50% complete	80
Sailing	5 (3)	4 males 1 female	54 (32–71) years	13.4 (8–35) days	Cervical spine Lumbar spine	Fall overboard	60–100% incomplete	20
Skiing	2 (1.2)	1 male 1 female	36 (33–39) years	2.5 (2–3) days	100% Thoracic spine	Falls during ski jumping	50–100% complete	50
Cycling	8 (4.2)	6 males 2 females	35 (19–63) years	15 (1–70) days	75% cervical spine 25% thoracic spine 12.5% lumbar spine	Fall from bicycle	38–66% complete	50
Paragliding	2 (1.5)	2 males	36.5 (33–40) years	15.8 (8–23) days	100% lumbar spine	Axial compression following inappropriate landing technique	50–100% incomplete	50
Parachuting	4 (2.3)	3 males 1 female	31 (21–40) years	22.5 (10–29) days	50% lumbar spine 25% cervical spine 25% thoracic spine	Inappropriate landing technique	25–100% incomplete	75
Motor racing	2 (1.2)	2 males	25 (18–31) years	17.5 (2–33) days	Thoracolumbar jxn	Collisions on track	0%	50
Gymnastics	1 (0.6)	1 female	23 years	4 days	C3/4 subluxation	Hyperextension injury	0%	0
Jet ski	1 (0.6)	1 female	21 years	16 days	L4 #	Hyperextension injury	0%	0



National Spinal Injuries Unit 2014 -

Old



2014





Results 2010 – 2014

- Over 10yrs (1993-2003): 8
- Over 5 yrs (2010 – 2014): 53
- Average age 44.3 yrs
- 19 male (79.2%) vs 5 female (20.8%)
- 5 (20.8%) had spinal cord injuries
- 7(29%) went on to have surgery



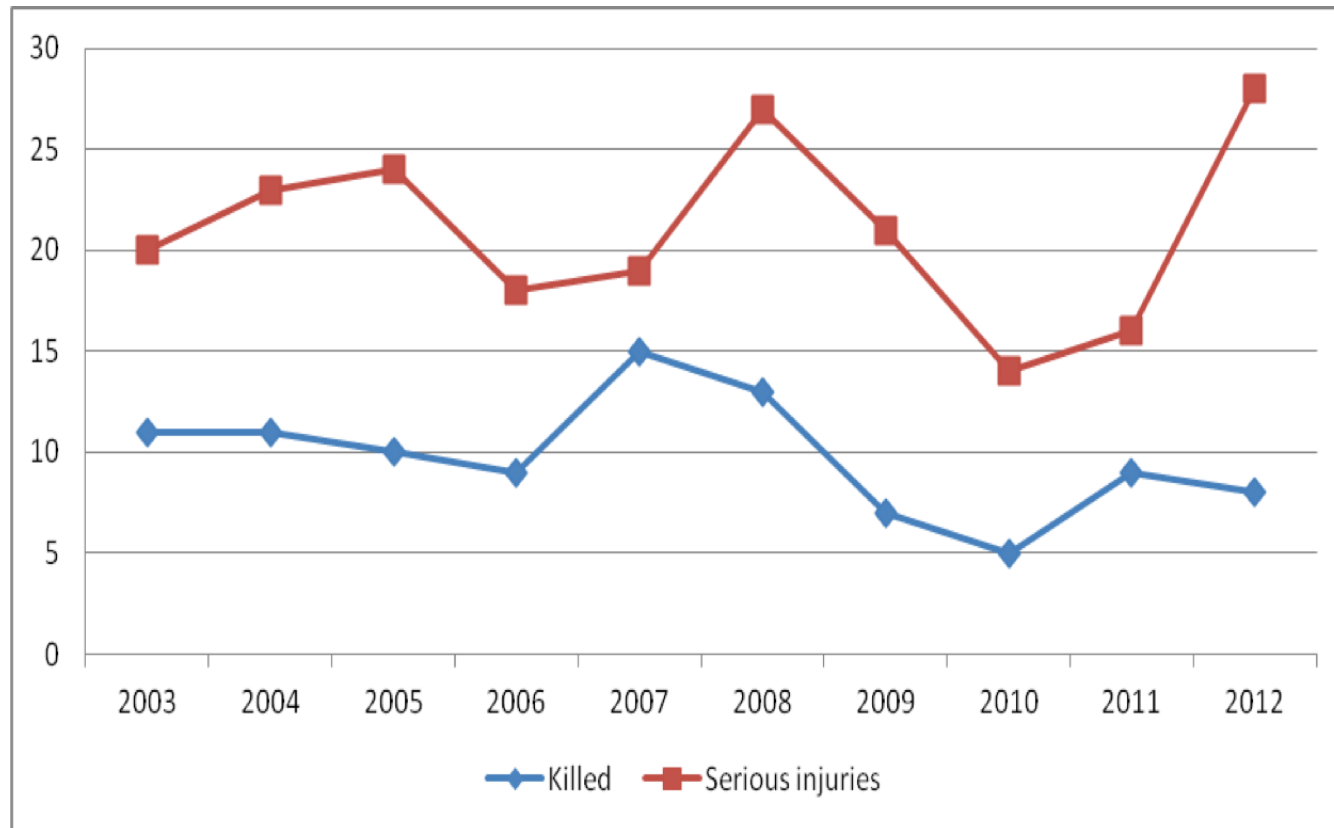
2010 – 2013

RSA / NSIU

Year	NSIU Car	NSIU Motorcycle	RSA Motorcycle Recorded Deaths	NSIU Bicycle	RSA Bicycle Recorded Deaths	Trauma
2010	41	19	17	5 (3%)	5	193
2011	36	14	17	3 (2%)	9	157
2012	54	8	19	9 (6%)	8	150
2013	53	6	27	15 (8%)	5	178
2014	24	8		21 (12%)		163
% change	-41%	-57%	+58%	+320%	0%	-16%



Cyclist deaths/ serious injuries, 2003-2012 (RSA)





Epidemiology Spinal Injuries

- Worldwide variations in epidemiology
- Developing world higher incidence

World Cup Laborer deaths

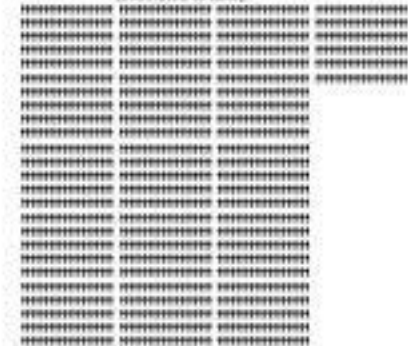
South Africa, 2010: ■

Brazil, 2014: ■■■■■■

Russia, 2018: ■■■■■■■■■■
(to date)

 reported.ly

Qatar 2022:
(estimated to date)



Sources: Al Jazeera, The Guardian, Openair Qatar





Western World

- US 27-47 cases/ million
- Ireland >240 cases p.a. (53 / million)
- Ireland 50 - 60 Spinal cord injuries per annum



Epidemiology of Spinal Injuries

- Average age 30yr
- Male: Female 5:1
- RTA >50%
- Falls 20%
- Sports 10%
- Increasing incidence from falls in elderly population (5 to 12/100,000 from 1970-2004)

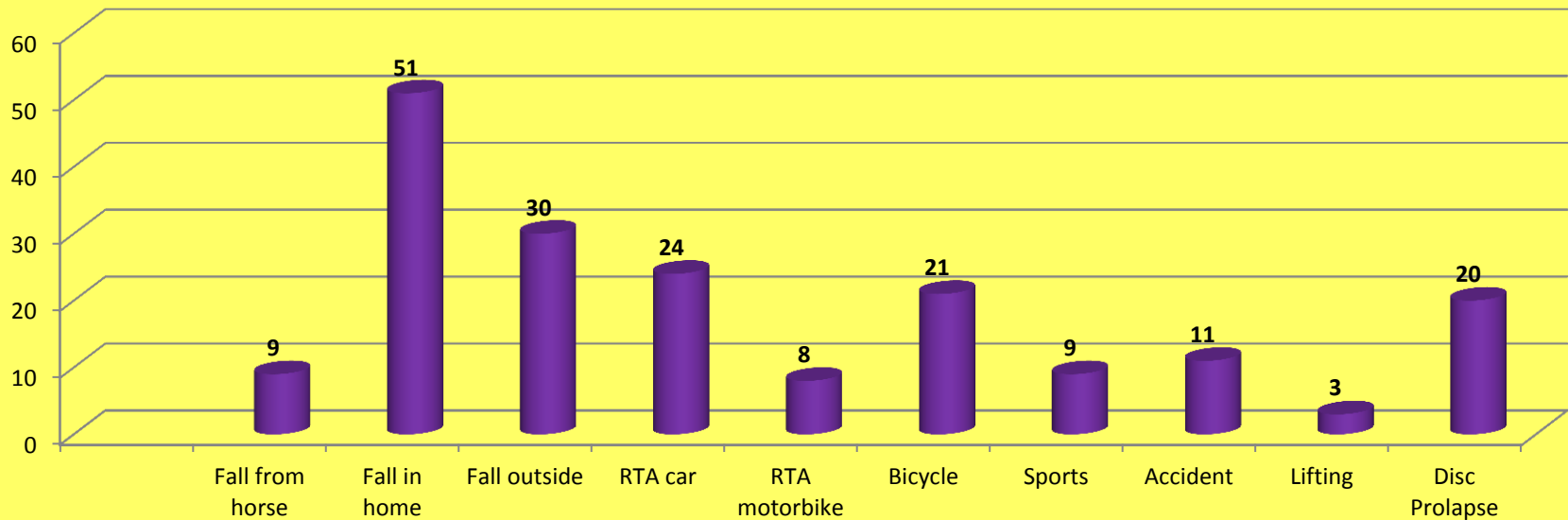
Bracken MB et al. Am J Epidemiol 1981;113:615-22.

Fisher CG. Spine 2005; 30: 2200-7.



Ireland:

NSIU Spinal Admissions 2014



N = 242 Trauma cases (58% Total Operative Cases)
N= 62 spinal cord injuries



Spinal Cord Injuries

- Improved survival over last 30 years
- Pre-hospital SCI deaths:
 - 1970: 38%
 - 2000: 15.8%
- Improved vehicle safety
- Improved pre-hospital care

Dryden DM. Can J Neurol Sci 2003;30:113-21

Burke DC: Aust NZ J Surg 1985; 55: 377-382



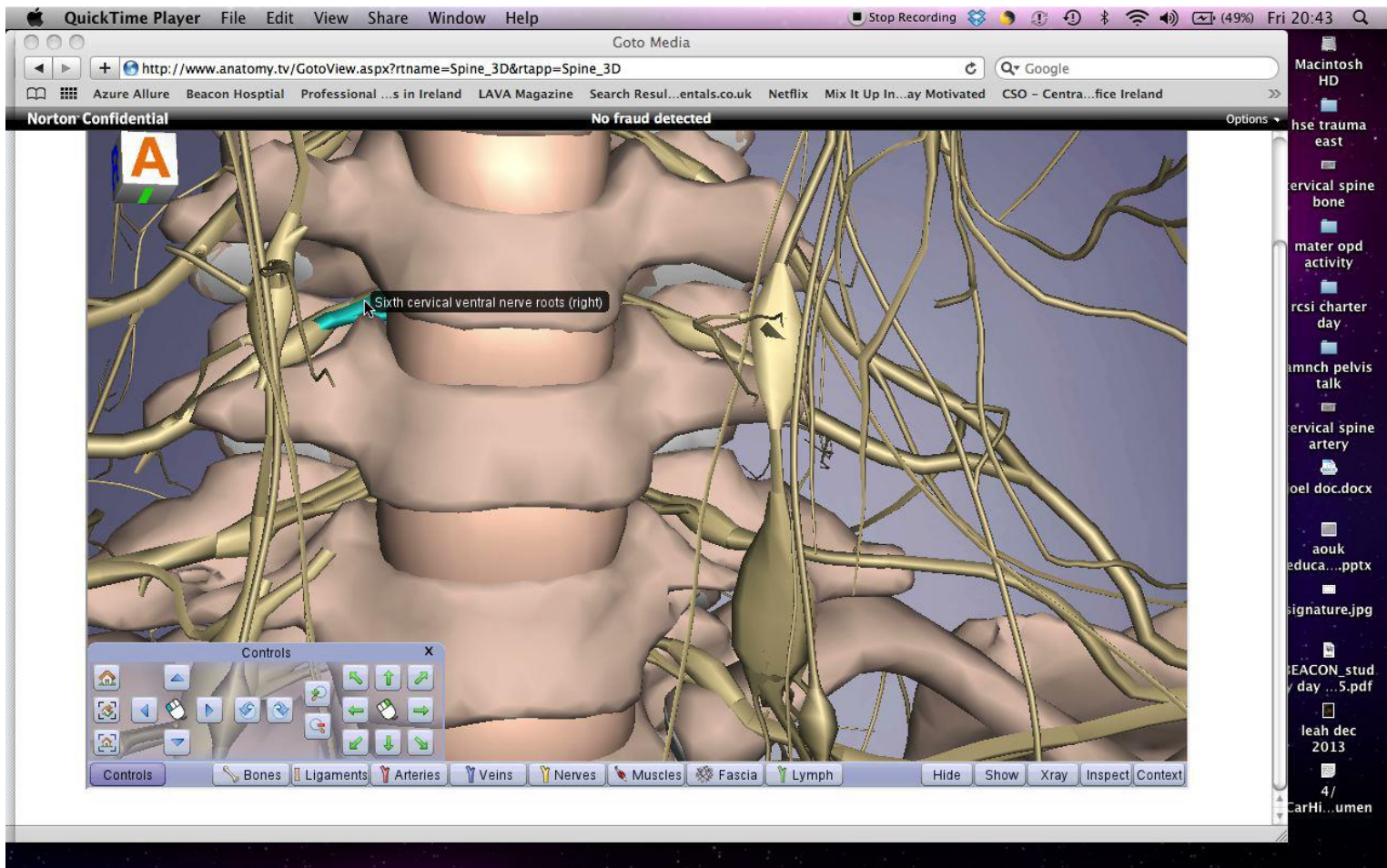
Cervical Spine Trauma: Spinal Cord Injuries

- 40% complete
- 40% incomplete
- 20% no cord or only root injury

Rizzolo et al Spine 1994



Spine Anatomy

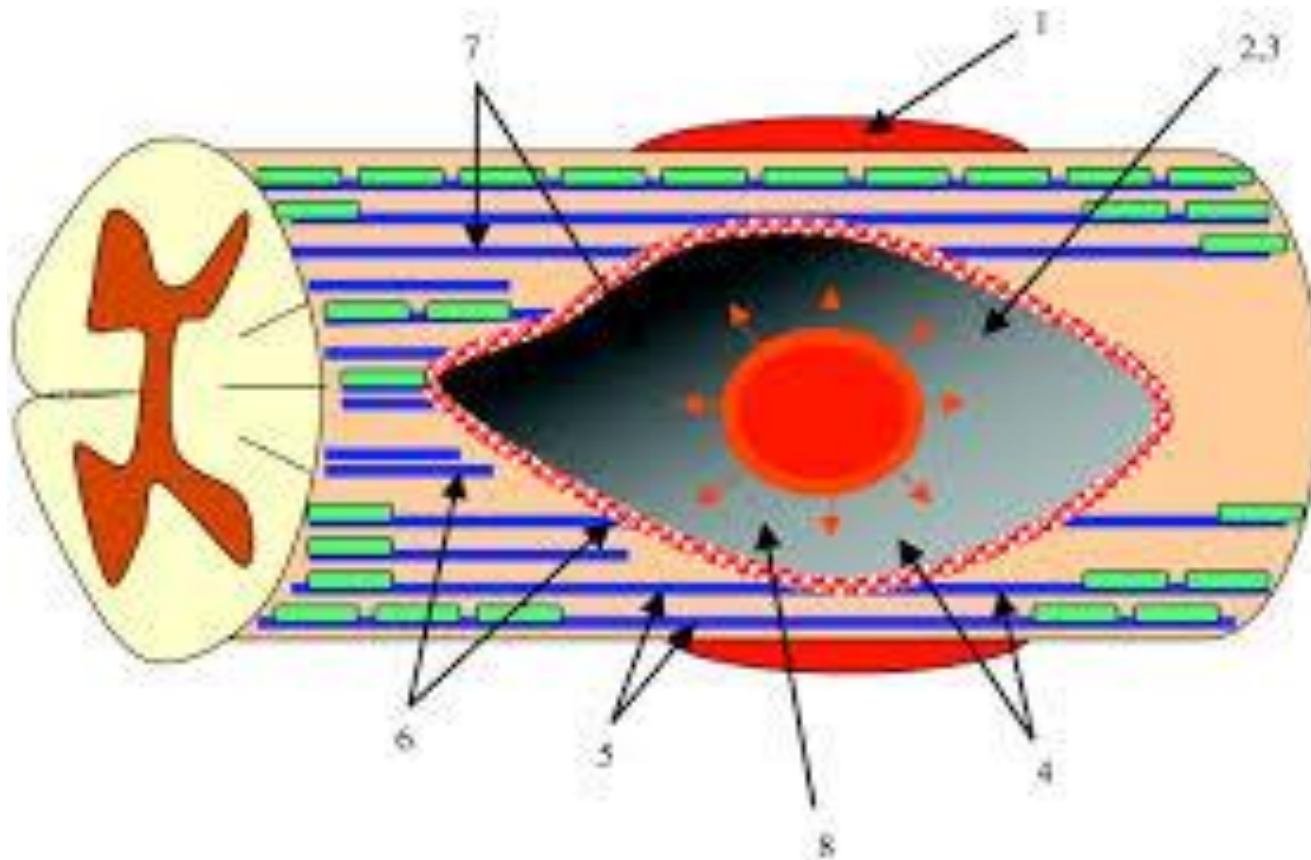




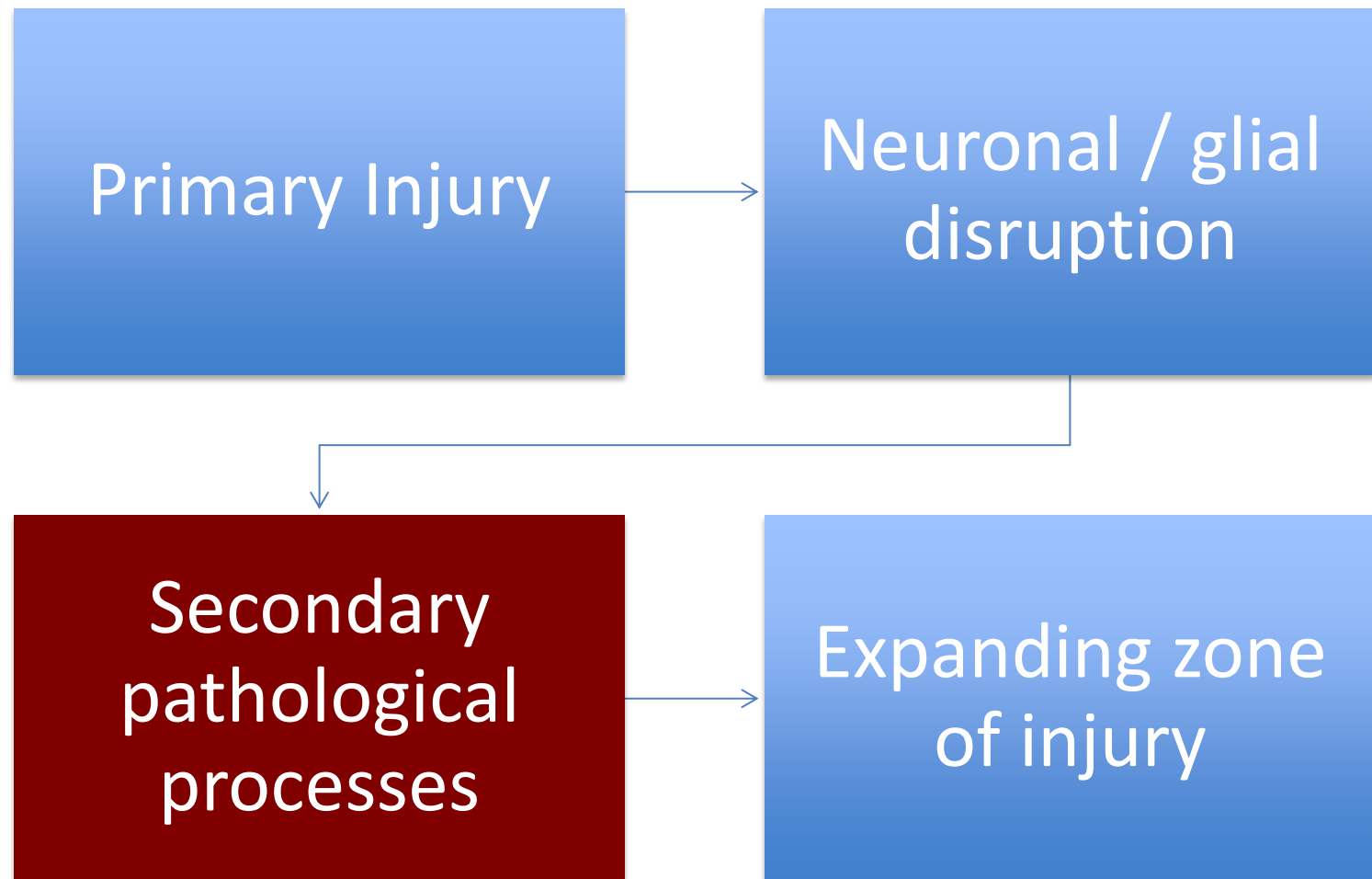
Classification of Neurologic Injury

- Complete Cord Injury
- Nerve Root Injury
- Incomplete Cord Injury
 - Brown-Sequard Syndrome (best prognosis)
 - Central Cord Syndrome (most common)
 - Anterior Cord Syndrome (worst prognosis)
 - Posterior Cord Syndrome (rare)

Primary Spinal Cord Injury: Already Occurred



Cascade of Injury





Pathophysiology of Spinal Cord Injury - Primary Injury

Primary mechanical insult
(impact, compression)



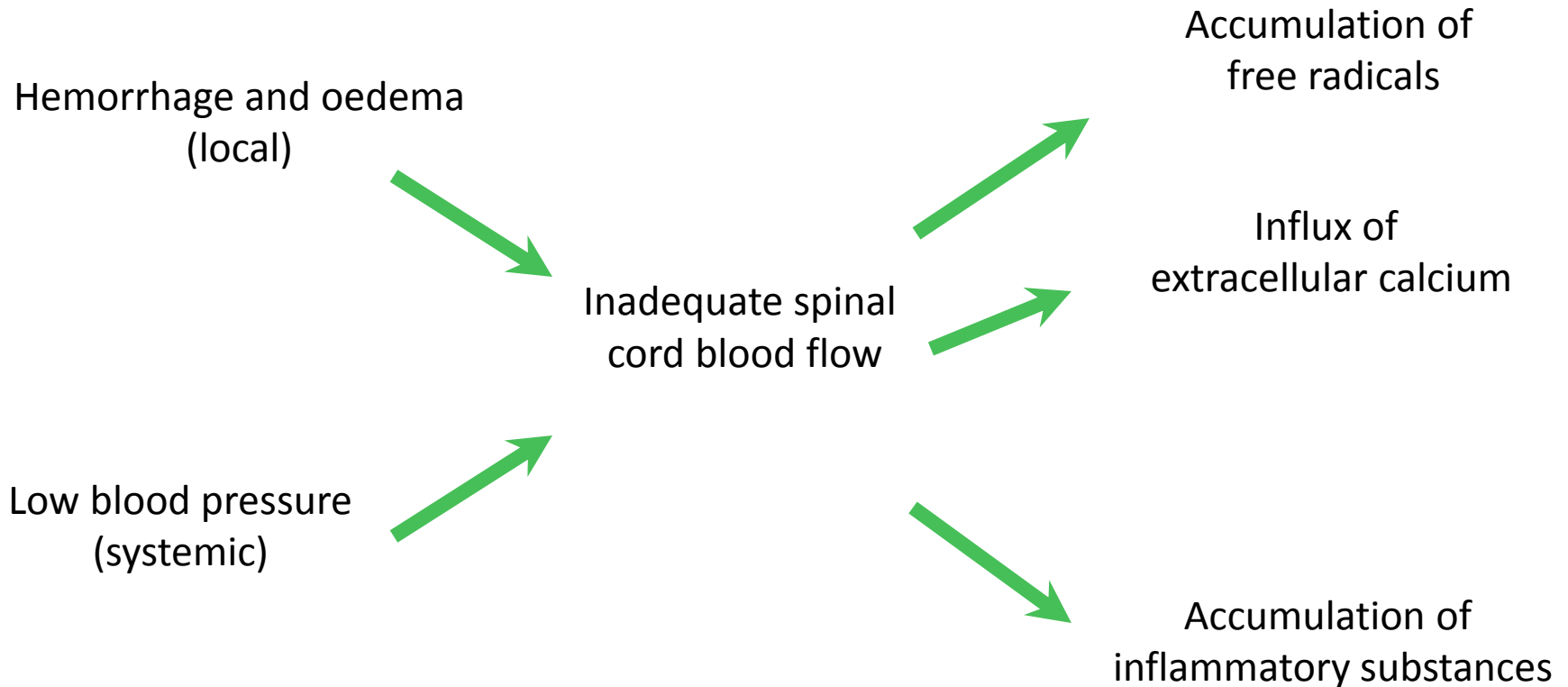
Damage of nerve cells, axonal tracts, blood vessels



Hemorrhage and edema



Pathophysiology of Spinal Cord Injury - Secondary Injury





Racer

- 65% were cycling a racer style bike
- All 3 patients with ASIA A disability
- 2 in head down position





Level of Injury

	No.	%
Cervical	17	70%
Thoracic	7	30%
Lumbar	0	0

Case 1

- Fall from bicycle
- Helmet: multiple fragments
- Sensory / motor level T6
- GCS 15
- T45 fracture dislocation
- Fracture sternum
- Cord transection
- Mediastinal haemorrhage



Case 2

- Front fork fracture
- 32kph velocity
- Hyperextension injury
- Helmet - No head injury
- Fracture dislocation C5/6
- Haematoma & airway compromise
- Complete cord injury
- Motor level C5





Principle of Management: Prevent Primary /Secondary Trauma

- Prevent (further) neural trauma
- Resuscitation
- Stabilise spinal column
- Rehabilitation
- Early mobilisation
- Facilitate nursing care

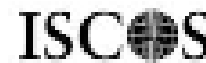


Patient Name _____

Examiner Name _____ Date/Time of Exam _____



INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY



MOTOR
KEY MUSCLES
(grading on a 5-point scale)

	R	L
C5	<input type="checkbox"/>	<input type="checkbox"/>
C6	<input type="checkbox"/>	<input type="checkbox"/>
C7	<input type="checkbox"/>	<input type="checkbox"/>
C8	<input type="checkbox"/>	<input type="checkbox"/>
T1	<input type="checkbox"/>	<input type="checkbox"/>

UPPER LIMB TOTAL (sum of R/L) ☐ + ☐ = ☐

Comments: _____

	R	L
L2	<input type="checkbox"/>	<input type="checkbox"/>
L3	<input type="checkbox"/>	<input type="checkbox"/>
L4	<input type="checkbox"/>	<input type="checkbox"/>
L5	<input type="checkbox"/>	<input type="checkbox"/>
S1	<input type="checkbox"/>	<input type="checkbox"/>

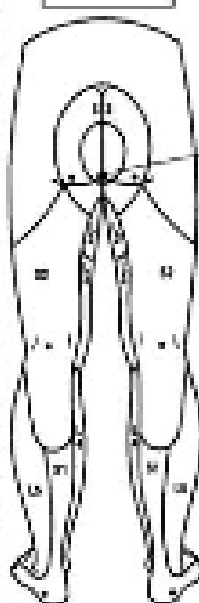
(NOC) Voluntary heel contraction (N/A) ☐

LOWER LIMB TOTAL (sum of R/L) ☐ + ☐ = ☐

	LIGHT TOUCH		PIN PRICK	
	R	L	R	L
C2				
C3				
C4				
C5				
C6				
C7				
C8				
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				
T11				
T12				
L1				
L2				
L3				
L4				
L5				
S1				
S2				
S3				
S4-5				

TOTALS (sum of R/L) ☐ + ☐ = ☐

0 = absent
1 = altered
2 = normal
NT = not testable



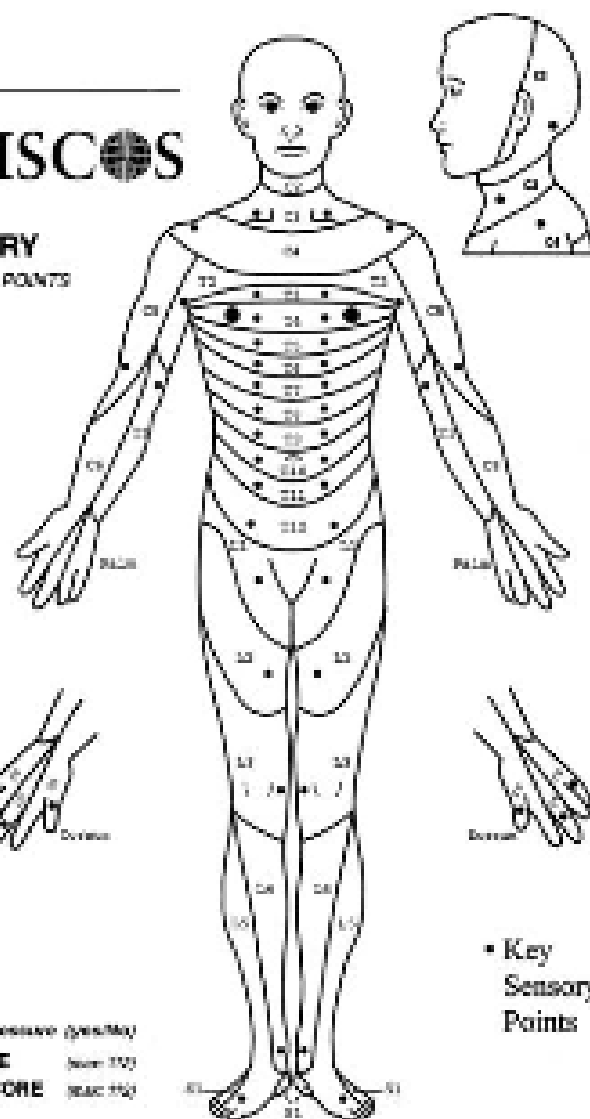
(DAP) Deep anal pressure (sum of R/L) ☐ + ☐ = ☐

PIN PRICK SCORE (sum of R/L) ☐ + ☐ = ☐

LIGHT TOUCH SCORE (sum of R/L) ☐ + ☐ = ☐

SENSORY

KEY SENSORY POINTS



• Key
Sensory
Points

NEUROLOGICAL LEVEL

Derived from sensory level with normal function

	R	L
SENSORY	<input type="checkbox"/>	<input type="checkbox"/>
MOTOR	<input type="checkbox"/>	<input type="checkbox"/>

SINGLE NEUROLOGICAL LEVEL ☐

COMPLETE OR INCOMPLETE?

Intact perineal sensation or motor function in S4-5

ASIA IMPAIRMENT SCALE (AIS) ☐

ZONE OF PARTIAL PRESERVATION

But could have any preservation

	R	L
SENSORY	<input type="checkbox"/>	<input type="checkbox"/>
MOTOR	<input type="checkbox"/>	<input type="checkbox"/>



Prognosis: Injury & Age

- AIS A: series 70pts – none with distal motor function recovery at 2yr FU

Fisher CG et al. Spine (Phila Pa 1976) 2005;30(19):2200-2207

- AIS B:
- 50% recover sufficient LE strength to ambulate
- Better prognosis if pinprick preserved vs light touch alone

Waters et al. Arch Phys Med Rehabil 1994;75(3):306-311



Prognosis

- AIS C: 75% ambulatory
- AIS D: majority ambulatory
- Age: AIS C pts
- ≥ 50 yo 42% ambulatory on discharge
- <50 yo 91% ambulatory on discharge
 - *Burns SP et al. Arch Phys Med Rehabil 1997;78(11):1169-1172*
- Complete tetraplegics: poor prognosis but often some motor recovery in zone of partial preservation



Life Expectancy SCI

- 1 year survival 95% of general population
- 10 year survival 92% of general population
 - Connor PJ. Arch Phys Med Rehab: 2005: 86:37-47
 - Frankel HL: Spinal Cord 1998:36:266-74.
- Respiratory Infections leading cause of death



Treatment objectives in acute SCI

- Immobilization of spine to prevent further neurologic injury
- Minimization of hypoxia and ischemia at local site of the spinal cord injury
- Prevention of secondary injury by pharmacologic intervention

» Delamarter et al. JAAOS, 1999



Biomechanical Support of C collars

- 6-10% risk of neurological deterioration after medical / EMT input

Harrop JS. Spine 2001;26: 340-346.

- Helps maintain neutral alignment
- Proprioceptive cues to pt

- Cadaveric Study:
Unstable spinal injury
- Rigid collar vs no collar
similar amounts of motion
- In line immobilisation
mandatory for transfers

Rechtine GR. J Trauma 2004; 57:609-11.



Biomechanical Basis for Spine Boards

- Standard of care in US
- Respiratory compromise
- Pressure areas
- Use for transfer only
- Vacuum mattresses in EU
- Increased comfort



Acute Management of Cervical Spinal Cord Injury

- 1) Maintenance of adequate systolic BP > 90 mm Hg
- 2) 100% O₂ sat via nasal cannula
- 3) Early diagnosis
- 4) Early surgery increasingly important
- 5) Role of pharmaceutical agents controversial

Early versus Delayed Decompression for Traumatic Cervical Spinal Cord Injury: Results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS)

- Decompressive surgery < 24 hours
- 20% of patients ≥ 2 grade improvement on the American Spinal Injury Association (ASIA) scale
- 20% less complications (OR 2.57)
- Decompressive surgery > 24 hours.
- 8% of patients ≥ 2 grade improvement on the American Spinal Injury Association (ASIA) scale





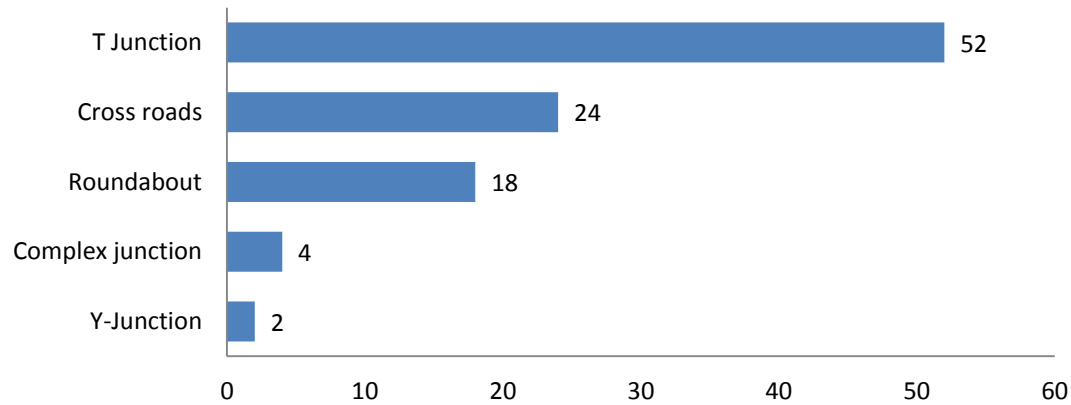
Predicting Site of Accident?



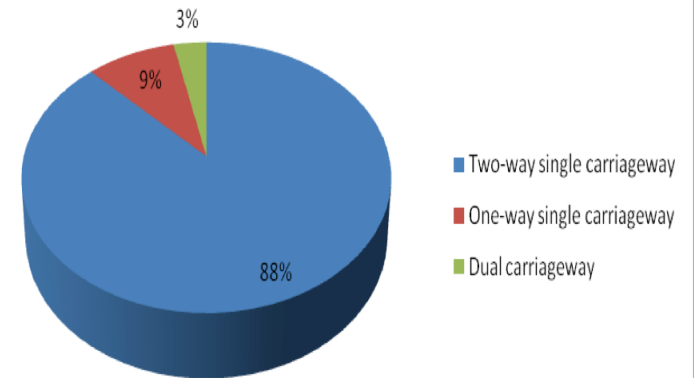


RSA 2012

% Breakdown of cyclist injuries occurred at a junction (49% total)



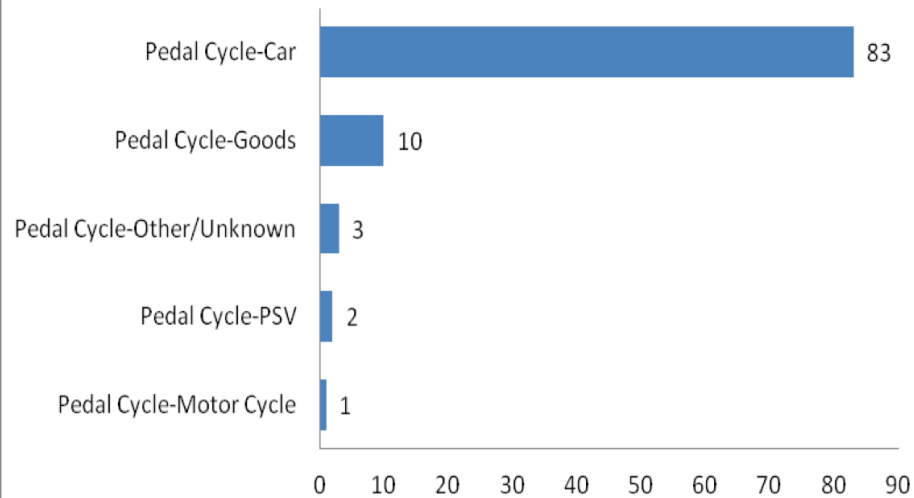
% of Cyclist injuries by road type



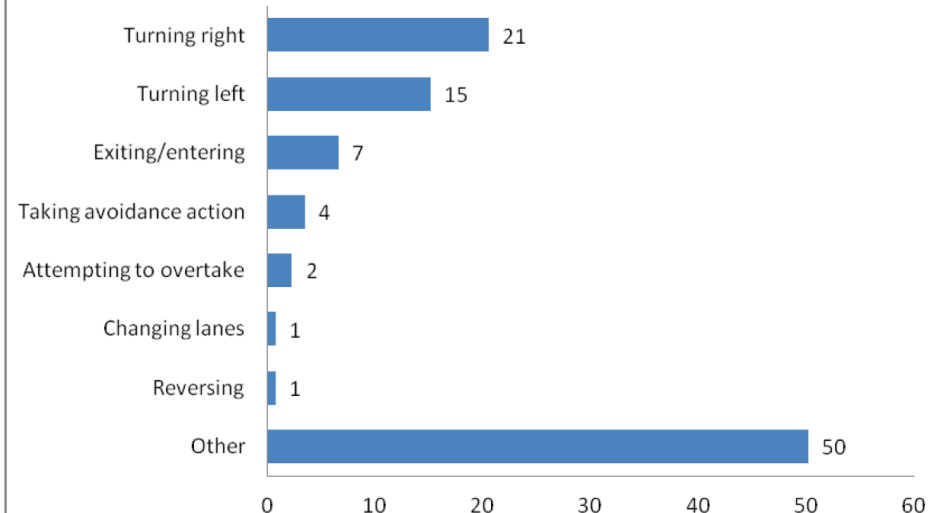


RSA 2012

% of cyclist injuries by vehicles involved



% of cyclist injuries by driver manoeuvres



Vehicle manoeuvres of drivers

Majority of cases (586/630) cyclists were injured due to a collision with another vehicle



Mechanism of Injury Canada

Table 3. Specific mechanism of injury distribution*

Mechanism	Group; no. (%)			p value
	Overall, <i>n</i> = 258	Street cyclists, <i>n</i> = 209	Mountain bikers, <i>n</i> = 49	
Fell off bicycle	120 (46.5)	93 (44.5)	27 (55.1)	0.20
Attempted to avoid a person, animal or object	5 (1.9)	5 (2.4)	0 (0)	
Rode down a hill at high speed	19 (7.4)	19 (9.1)	0 (0)	
Hit a speed bump	2 (0.7)	2 (0.9)	0 (0)	
Lost balance, speed-related or other cause	94 (36.4)	67 (32.0)	27 (55.1)	
Fell while attempting a jump or trick	29 (11.2)	19 (9.1)	10 (20.4)	0.041
Veered and fell off cliff, roadside or embankment	14 (5.4)	6 (2.9)	8 (16.3)	0.001
Collided with a person, animal or object other than a motor vehicle	28 (10.9)	25 (12.0)	3 (6.1)	0.31
Collided with a parked automobile	7 (2.7)	7 (3.3)	0 (0)	
Hit by a motor vehicle while bicycling	58 (22.5)	58 (27.8)	0 (0)	
Hit by a commuter train while crossing tracks	1 (0.39)	1 (0.48)	0 (0)	

**p* values not afforded when event rates too small to compare or when comparisons would not be meaningful (e.g., collision with parked car while mountain biking).



Road environment: Canada

- High Risk
- Multilane roundabouts without designated cycle path
- Sidewalks / shared cycle pedestrian paths higher risk
- Major > Minor roads
- Bicycle facilities decrease risk



Severity of Urban Cycling Injuries

Predictors Canada

- Older age
- Collision with a motor vehicle (31% admissions)
- Downhill grade
- Higher motor vehicle speeds
- Sidewalks
- Multiuse paths and local streets



Accident Location

(n=13,684 cyclist casualties) France

	Learning: 0-10yr	Sports: Teens / Non urban adult	Adult Commute
Collision with motor vehicle (%)	8%	17%	31%
% Serious Casualties (MAIS >3)	4%	11%	7%

Higher incidence of urban commuter injuries

Urban cyclists less severely injured – more falls from bikes / lower speeds

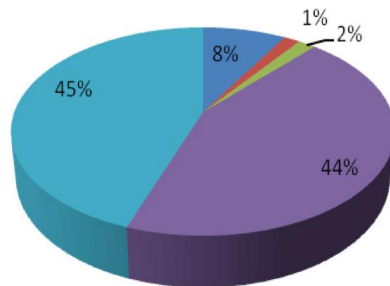
Higher incidence of internal injuries with MVA collisions



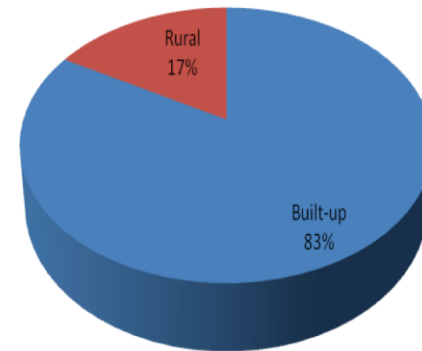
Urban / Rural

2012 cyclist injuries by trip purpose

- To/from work
- To/from school
- To/from home
- Other leisure
- Unknown/Not stated



Cyclist injuries by urban/rural





Video Analysis of Helmet Cams

Commuter collisions/near-collisions

- 12 cyclists
- 127 hours video footage
- 89% of cyclists travelled in a safe/legal manner
- Frequent head checks suggest cyclists had high situational awareness
- 87% vehicle driver at fault
- 83% no post-event driver reaction



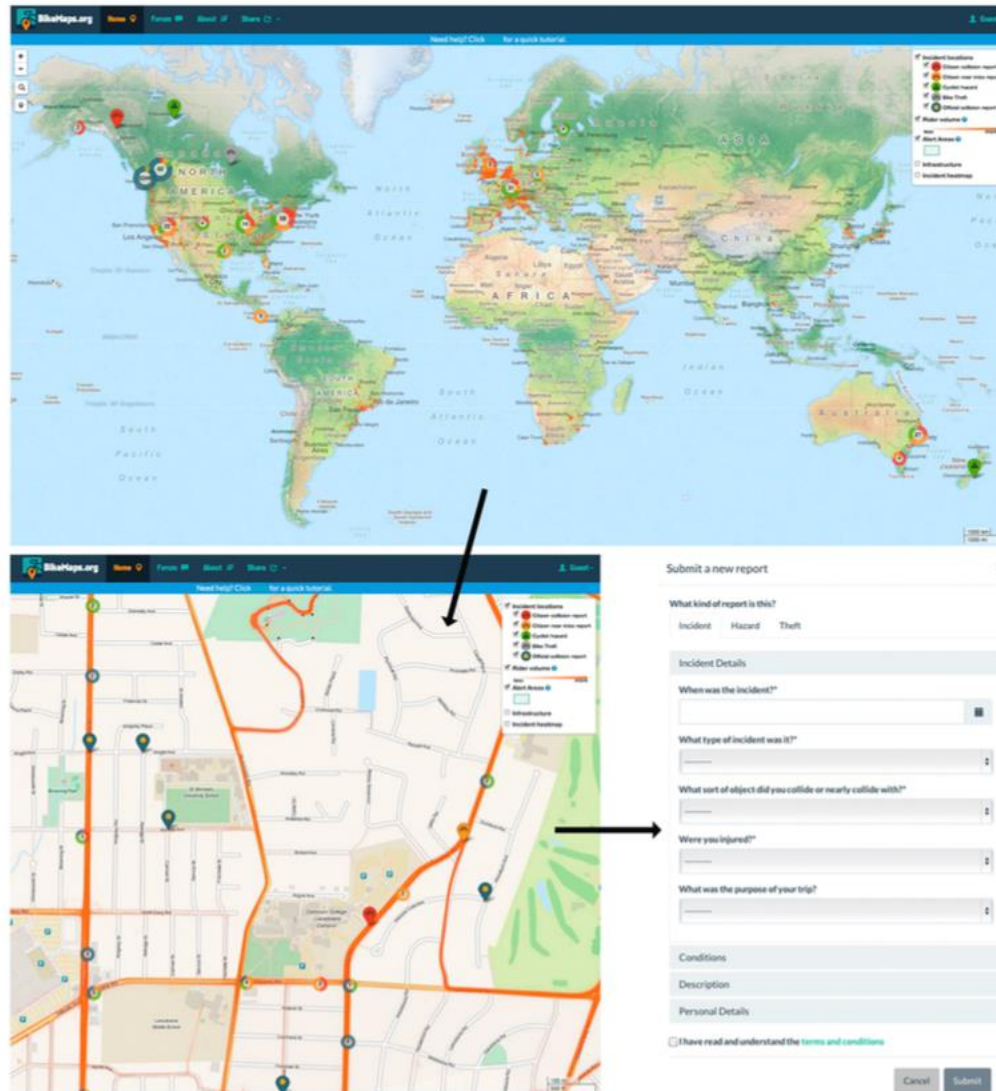


Video Analysis of Helmet Cams

Commuter collisions/near-collisions

- 54 events
- 2 collisions
- 6 near-collisions
- 46 incidents
- Sideswipe commonest incident (40.7%).
- 70% events occurred at an intersection/intersection-related location
- Event severity \approx
- other vehicle involved
- visual obstruction
- vehicle location ($p < 0.05$).

On-Line App Canada



Bikemaps.org

FIGURE 1 | BikeMaps.org is a global tool for citizen mapping of cycling collisions, near misses, hazards, and thefts. The upper panel shows the website and global map. The lower panel – left is a close up of the map and

the view typically used by the citizen mapper when adding data. The lower – right is an example of the table used to collect attribute data on each cycling incident.



Summary: Planning

- Majority of road accidents internationally due to falls / rider error – 20-30% collision related
- 83% Ireland: collision related -
?underreporting of falls
- Segregation of bicycles from other road users



Education

- Clear benefit of helmet wear
- Targetted educational campaign – young males
- Riding skills



Medical

- Primary Injury already occurred
- Prevent secondary injury
- Avoid increase in zone of injury
- Preserve cephalad roots
- **Dedicated spine trauma centre**
- **Early spine surgery**

