# Influence of Gender, Height, Weight, Age, Seated Position and Collision Site related to Neck Pain Symptoms in Rear End Impacts

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***Abstract*** Rear end vehicle collisions can result in occupants suffering neck pain symptoms of varying degree and duration. These injuries are generally called whiplash injuries and they are common and costly. This study analyses the occurance and duration of neck pain symptoms of one particular vehicle make with focus on the influence of occupant specific information. Data collected from a Swedish vehicle make, model year 1993 up to model year 2007 at a maximum of three years old, were analysed.

The results from this study show that passengers are more likely than drivers to suffer neck pain symptoms, in crashes that occurred in that particular make of car. No significant differences in risk related to age, gender weight, and height could be identified, except for: Females aged 35-44 had higher risk to have long and medium term neck pain symptoms than males in the same group of age. Males aged >=65 had higher risk to have long and medium term neck pain symptoms than males aged 35-44. Females in group "Braking" had higher risk of any type of neck pain symptoms than males.

Where the occupant was seated in the front seat of the carinfluenced the occurance of neck pain symptoms and their duration for both males and females, with passengers posing a higher risk of suffering neck pain symptoms compared to drivers. Of the drivers, 17 percent reported neck pain symptoms compared to 44 percent of the passengers. When grouped into the categories males and females, 15 percent of the male and 19 percent of the female drivers reported neck pain symptoms compared to 44 percent of the male and 43 percent of the female passengers. With respect to the different collision sites, rear end collisions at traffic lights most often resulted in occupants reporting neck pain symptoms. Collisions in roundabouts most often resulted in different impact scenarios and occupants reported suffering neck pain symptoms of mid and long term duration.

The result of this study indicates the need for improved understanding of the differences between driver and passenger response in different driving scenarios. In addition, occupant charactersisics should also be studied.

***Keywords*** Neck pain symptoms, Rear impact, Seat, Injury protection

## I. INTRODUCTION

Neck pain symptoms, of varying degree and duration sustained in low severity vehicle collisions, commonly denoted whiplash injury, are a worldwide problem. Such injuries are costly since they are frequent and can lead to long lasting pain and disability. In Europe alone, the annual cost for whiplash injuries has been estimated to be 10 billion Euros [1]. Whiplash injuries account for ~70 percent of all crash-related injuries leading to disability [2]. The majority of those who experience initial neck symptoms following a car crash recover within a few weeks or months of the crash [3]. However, 5–10 percent of individuals will experience permanent disabilities of varying degrees [3–5]. These injuries occur at relatively low speed changes (typically <25 km/h) [6–7] in impacts from all directions. Rear impacts, however, featured most frequently in the injury statistics [8].

Since the mid-1960´s, statistical data have shown that females have a higher risk of sustaining whiplash

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injuries than males, even in similar crash conditions [9–18]. According to these studies, the whiplash injury risk is up to three times higher for the females compared to the males.

Different seat designs and whiplash protection systems have shown different degrees of protection against such injuries [19]. Furthermore, the whiplash injury risk is dependent on in which seat the occupant is positioned. Some studies have found that the whiplash injury risk is greater in the front passenger seat compared to the driver seat [13][20]. Other studies have reported that the whiplash injury risk is greater in the driver seat compared to the front passenger seat [21–22]. Several studies have indicated that front seat occupants have a higher whiplash injury risk than rear seat occupants [20][22–24]; however, when looking at the long term injuries, [17] found a different correlation for the females. In that study a paired comparison was performed on all neck injuries reported to the Swedish insurance company Folksam, following rear impacts during 1990–1999.

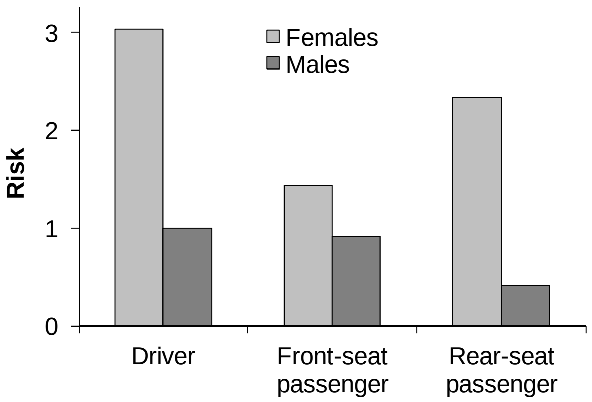


**Fig. 1.** The risk of permanent whiplash injury in relation to the male driver risk (normalised to 1) for different seating positions in rear impacts. Based on [17].

The males had a lower injury risk in the rear seat compared to the front seat, while the females had a considerably higher injury risk in the rear seat; the lowest risk for the females was found for the front passenger seat (**Fig. 1**). The risk of permanent disability was three times higher for female drivers compared to male drivers. Similarly, permanent disability was 1.5 times higher for female front seat passengers and more than five times higher for female rear seat passengers.

The objective of this study was to evaluate the influence of front seat seating position, crash location, weight, height, age and gender on the risk of neck pain symptoms in a rear collision.

## II. METHODS

### *Description of the study*

Data collected from the particular Swedish vehicle make, model year 1993 up to model year 2007 at a maximum of three years old, were analysed. The dataset contained single event rear end impacts resulting in repair claims containing occupant specific data of both uninjured and injured occupants. A questionnaire was sent out to the owner of the car, requesting information about occupant age, weight,height, seatbelt usage, etc. The data were analysed to study the influence of gender, height, weight, age and seating position in relation to duration of neck pain symptoms.

All new vehicles sold in Sweden, by the vehicle make analysed in this study, is covered by a three year warranty. During this period, any collision requiring repair is covered by the warranty. The insurance company collected data from all rear end collisions in model year 1993 up to model year 2007 vehicles[1], at a maximum of three years old at collision date. A questionnaire was sent to the owner of the vehicle collecting additional information about the persons involved in the crash. Some collisions were found to be outside the scope of this study. Cases excluded were multiple event collisions, parking lot accidents with no occupants in the struck vehicle, collisions involving a motorcycle or moped and duplicate cases. This resulted in 1,142 cases of rear end collisions involving 1,345 individuals. Information from accident reports, repair valuations, pictures of the struck vehicle and police reports was available. However, all categories of information were not available for all cases. In some cases, only an accident report or repair valuation was available, whereas in other cases, different combinations of the above information were available.

The dataset consisted of two different collection periods. Survey 1 was performed for vehicles with model year 1993 up to 1999 and Survey 2 with model year 2000 up to 2007. Some of the approaches differed between the two surveys and are described below.

[1] Saab 9-3, model year <2003 and Saab 9-5 are equipped with the SAHR gen I whiplash protection system. Saab 9-3, model year ≥2003 are equipped with the SAHR gen II whiplash protection system.

Survey 1 & 2: Police reports and additional information gave a detailed view of the crash circumstances and course of events. The accident reports contained information on individuals or at least the drivers involved, crash circumstances and injury outcome. Survey 2 only: Repair valuations included repair cost and parts repaired or replaced. Pictures of the struck vehicle gave increased understanding of the crash severity.

Survey 1: The change of velocity ($\Delta$v) was estimated based on comparison of pictures from crash-tested vehicles in the laboratory, i.e., deformations were compared cars crashed on the field with the cars that had been crashed in the crash-lab where $\Delta$v was documented.

Survey 2: Crash severity was classified based on information from the repair valuation. A damage severity scale from 1 to 5 was developed:

*Category 1*: lacquer and paint damage, sheet-metal dents, renewal of plastic details such as brackets for parking sensors as well as repair or replacement of the rear bumper.

*Category 2:* the bumper foam blocks had been renewed.

*Category 3:* the towing hook had been repaired or replaced.

*Category 4:* constructional beams had been repaired or replaced.

*Category 5:* the struck vehicle was in such bad shape that it had to be towed from the accident.

To obtain additional information about occupant height and weight, usage of seatbelt, etc, a questionnaire was sent by post to the owner of the vehicle and in some cases telephone interviews were conducted. Survey 1 was performed for vehicles with model year 1993 up to 1999 and Survey 2 model year 2000 up to 2007. The questionnaires were posted as follows:

- If any injuries were claimed in the accident report (Survey 1 & 2)
- If damage severity was classified as a 4 or 5, whether neck pain symptoms were reported or not (Survey 2)
- If damage severity was classified as a 3 and the vehicle was fitted with a towing hook, whether neck pain symptoms were reported or not (Survey 2)

In cases where the relevant individuals could not be reached, the duration of their neck pain symptom status was considered unknown. If a questionnaire had not been posted and passenger information was not available in the accident reports, the driver was assumed to be the sole occupant of the car.
Below is outline of how the occupants´ neck pain symptoms were categorised into four different categories, or into the category unknown or no neck pain symptoms:

NI: No neck pain symptoms
ST: Short Term neck pain symptoms (neck pain lasting up to one week)
MT: Medium Term neck pain symptoms (neck pain lasting more than one week but less than ten weeks)
LT: Long Term neck pain symptoms (neck pain lasting longer than ten weeks)
INJ: Only in Survey 1: If they noted some kind of neck pain in the injury report, but had not answered the questionnaire
N/A: Unknown status (information unavailable)

### *Description of the data set*

The dataset contained information about 1,345 individuals, mostly from Survey 2. Rear seat occupants below the age of 16 were removed from the dataset. **Table I** 'N red' shows the number of cases used for analysis in this study.

**TABLE I**

NUMBER OF OCCUPANTS INVOLVED IN REAR END COLLISION

| | Number (N) | Number(N red)[a] |
|---|---|---|
| Survey 1 | 203 | 180 |
| Survey 2 | 1,142 | 890 |
| Total | 1,345 | **1,070** |

[a] Occupants: only driver, front-seat passenger and aged 16 and older.

The response rate was approximately 60 percent from both surveys. In total, there were 223 responses from different households with information on 360 occupants. Of these occupants there were 303 individuals who satisfied the requirements (**Table II**, ‘Occupants (red)’).

**TABLE II**

SUMMARY OF THE TWO SURVEYS:NUMBER OF SENT QUESTIONAIRS, RESPONSES

| | Posted | Responses | Response rate | Occupants | Occupants (red) |
|---|---|---|---|---|---|
| Survey 1 | 99 | 57 | 58% | 85 | 78 |
| Survey 2 | 275 | 166 | 60% | 275 | 225 |
| Total | 374 | 223 | 60% | 360 | **303** |

In **Table III** the total number of occupants is presented. In some cases data were missing, denoted N/A.

**TABLE III**

THE GENDER, AGE, WEIGHT, HEIGHT AND THE DURATION OF NECK PAIN SYMPTOMS

| | Background details | | | | Injury details (*total sum=1,273*) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gender (n) | Age (n) | Weight (n) | Height (n) | NI (n) | ST (n) | MT (n) | LT (n) | INJ (n) | N/A (n) |
| **Survey 1** | **185** | **185** | **78** | **78** | **101** | **16** | **6** | **13** | **44** | **5** |
| **Driver** | **141** | **141** | **58** | **58** | **83** | **11** | **5** | **10** | **27** | **5** |
| Female | 19 | 19 | 8 | 8 | 10 | 2 | | 1 | 6 | |
| Male | 115 | 113 | 49 | 50 | 71 | 9 | 5 | 9 | 21 | |
| N/A | 7 | 9 | 1 | | 2 | | | | | 5 |
| **Passenger** | **44** | **44** | **20** | **20** | **18** | **5** | **1** | **3** | **17** | |
| Female | 30 | 28 | 14 | 16 | 11 | 2 | 1 | 3 | 13 | |
| Male | 8 | 7 | 4 | 4 | 1 | 3 | | | 4 | |
| N/A | 6 | 9 | 2 | | 6 | | | | | |
| **Survey 2** | **1,088** | **1,088** | **209** | **209** | **774** | **74** | **22** | **20** | **0** | **198** |
| **Driver** | **1,006** | **1,006** | **164** | **164** | **735** | **52** | **18** | **17** | | **184** |
| Female | 150 | 143 | 34 | 36 | 98 | 11 | 5 | 7 | | 29 |
| Male | 597 | 570 | 123 | 122 | 424 | 41 | 12 | 10 | | 110 |
| N/A | 259 | 293 | 7 | 6 | 213 | | 1 | | | 45 |
| **Passenger** | **82** | **82** | **61** | **61** | **39** | **22** | **4** | **3** | | **14** |
| Female | 45 | 40 | 33 | 32 | 23 | 17 | 2 | 1 | | 2 |
| Male | 31 | 24 | 19 | 19 | 14 | 5 | 2 | 2 | | 8 |
| N/A | 6 | 18 | 9 | 10 | 2 | | | | | 4 |
| **Total** | **1,273** | **1,273** | **303** | **303** | **875** | **90** | **28** | **33** | **44** | **203** |

**Table IV** shows that mean values of age were not significantly different in the dataset. The males were 17.8 heavier and 13.7 cm taller than females.

**TABLE IV**

MEAN VALUES OF AGE, WEIGHT AND HEIGHT

| | Age | Weight (kg) | Height (cm) |
|---|---|---|---|
| Females | 45.4 | 65.4 | 166.5 |
| Males | 45.9 | 83.2 | 180.2 |
| Difference | **0.5** | **17.8** | **13.7** |

***Statistical analysis***

Age, weight and height were divided into groups containing intervals of 10 due to if less intervals were selected, i.e., intervals of 5, the the number of observations in the dataset was too few in each group. Due to the low number of observations, predominantly in the group LT+MT, it was not possible to use the Chi-Square Test in this case. When performing this test, the expected values in separate cells must be >=5, which was mostly not the case. Therefore, Fisher’s Exact Test [35] was used instead, however, this test can only manage a

2x2-matrix. Therefore NI and ST were merged in order to obtain differences of NI +ST vs. MT+LT (P-values=p, if p<.05 = significant) when using the Fisher's Exact Test. The paired combinations were only conducted for groups greater than a minimum 20 observations.

## III. RESULTS

All cases contained information about gender, age, collision action, and collision site. Information about tow hook, weight, height and (Body Mass Index) BMI were collected for the cases of higher impact severity since the questionnaire for the major study (Survey 2) was sent to occupants in severe crashes. LT and MT were merged in all figures in order to reduce uncertainty due to the low number of observations. In most cases there were too few observations of passengers and therefore this group will not be presented due to its unreliability. If a group illustrated as a bar in the Figures consist of <20 observations, the bar have dotted lines, to illustrate the uncertainty due to the few observations in this group. All figures in the result section have tables of statistics including p-values in the Appendix.

***Driver–Passenger: Gender***

Of the passengers, 44 percent had reported some kind of neck pain symptoms in comparison to the drivers for which 17 percent had reported neck pain symptoms (**Fig. 2**). In **Fig. 2** drivers and front-seat passengers are divided into the categories Males and Females. There were marginal differences between males and females. Statistical significance tests confirm that there were no differences between the genders ($p_{Dr}$=.182, $p_{Pa}$=.733). For male drivers, the tendency to have LT or MT was lower than for female drivers. Male drivers and male passengers showed a relatively major difference of LT and MT (8%), but the statistical test (p=.094) indicates that the difference is not significant. Female drivers and passengers had similar amount of LT + MT symptoms; however, female passengers compared to female drivers had considerably more short-term neck pain symptoms. The male passengers had more short-term neck pain symptoms than the male drivers, equivalent to female passengers.

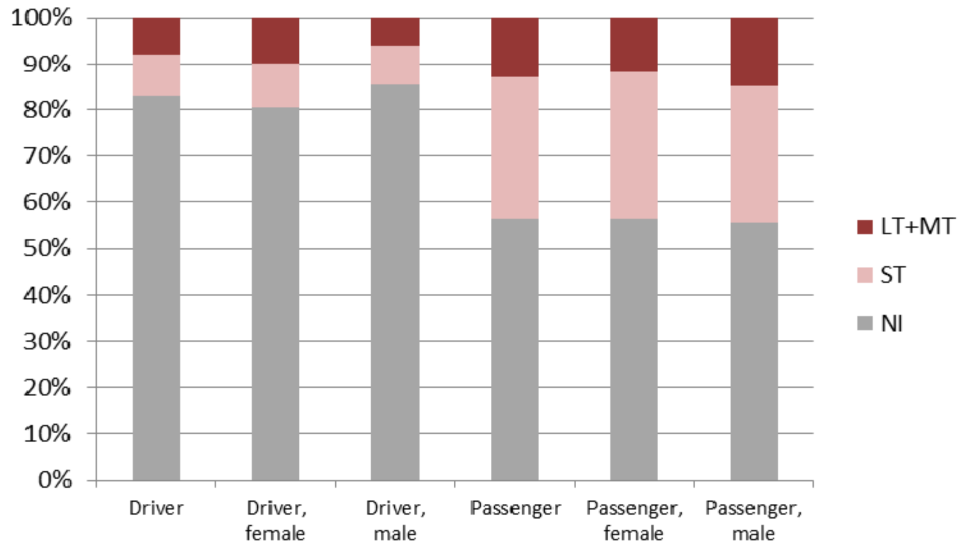


**Fig. 2**. The duration of neck pain symptoms, occupant front seat position and gender. ($n_{dr}$=715, $n_{pa}$=87)

Regarding severity of impact, a bias was found in the data showing slightly higher severity of the cases involving passengers.

***Driver: Tow hook and Gender***

There were no statistically significant results, but the it was apparent that the tendency for female drivers to have increased risk of medium and long term neck pain symptoms if the vehicle was fitted with a tow hook (**Fig 3**).

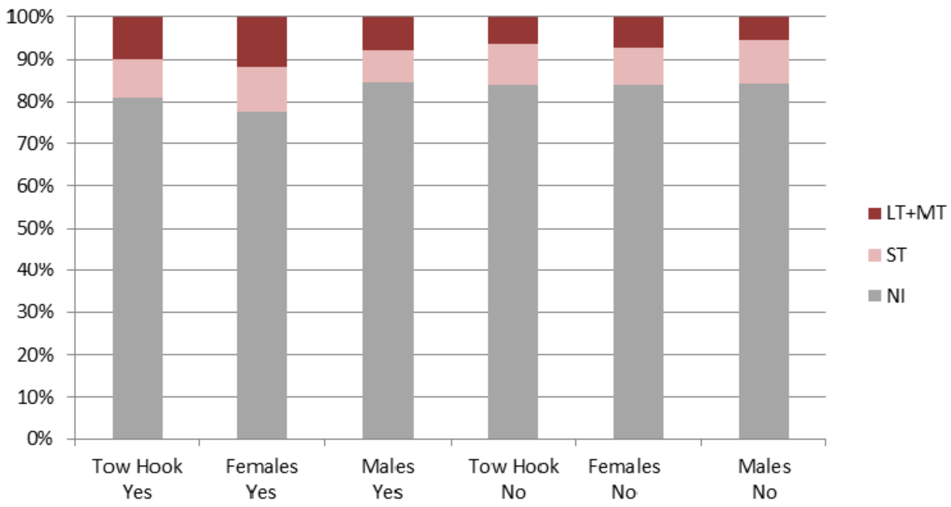


**Fig. 3.** The duration of neck pain symptoms of drivers with (yes) and without (no) tow hook, and gender. ($n_{no}$=293, $n_{yes}$=406)

***Driver: Age and Gender***

What influence age of the occupants has, is shown in **Fig 4 and 5**. Females, aged 35-44, had the highest risk of medium and long term neck pain symptoms, males in this group had the lowest risk. Fisher's Exact Test confirms that the differences are significant. Males, aged >=65 have higher risk of having LT and MT compared to the other age groups for males (significant between 35-44, p=.049). The observations for females, ages 16–34 and >=55, were too few to draw any conclusions from, for males the number of observations were too few for the ages 16-24.

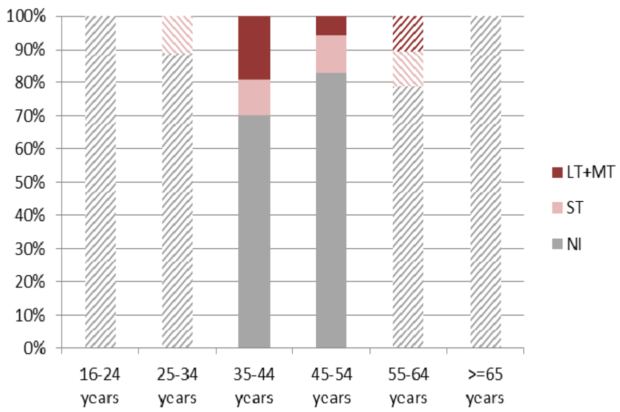


**Fig. 4**. The duration of neck pain symptoms, FEMALE distributed in age groups. (n=127)

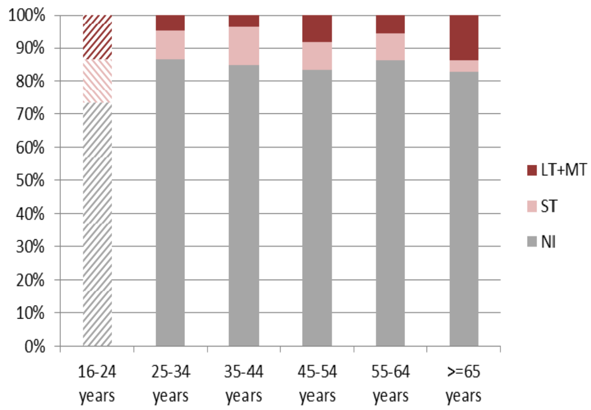


**Fig. 5**. The duration of neck pain symptoms, MALE distributed in age groups. (n=557)

***Driver: Weight and Gender***

The influence of weight of the occupants is shown in **Fig. 6-7**. Only weight group 60–69 (n=20) kg for the females had sufficient number of observations from which to draw any conclusions. (**Fig. 6**). The tendency was that males in weight groups 80–89 and 90–99 kg had decreased risk of MT and LT (**Fig. 7**). Due to the low number of cases in groups 60–69 kg (n=6) and 110 and higher (n=5), conclusions could not be drawn about these weight groups.

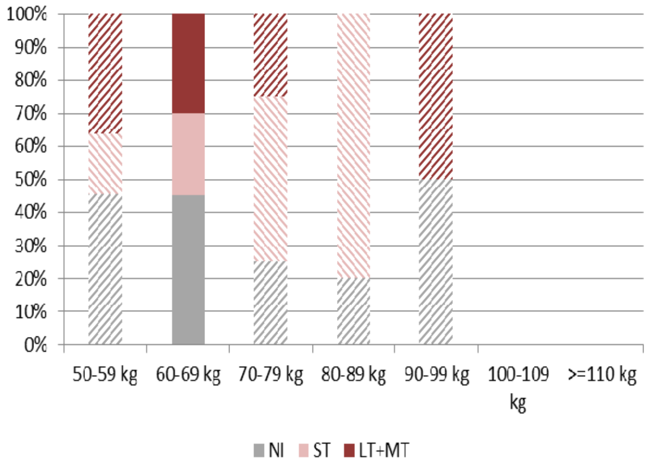


**Fig. 6**. The duration of neck pain symptoms, FEMALE distributed in weight groups. (n=42)

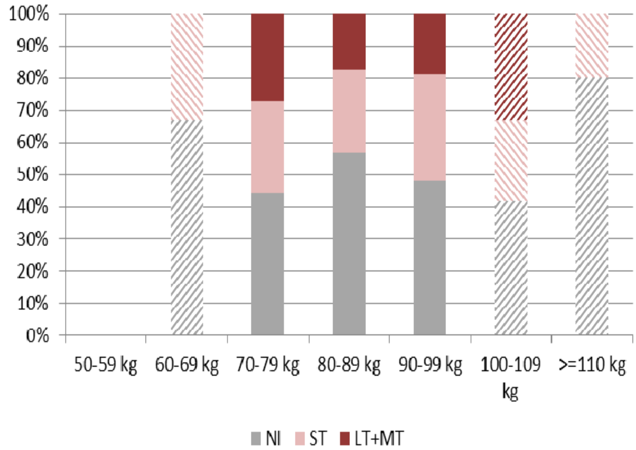


**Fig. 7**. The duration of neck pain symptoms, MALE distributed in weight groups. (n=167)

***Driver: Height and Gender***

The female height groups 160–169 (n=27) had sufficient number of observations in order to identify trends (**Fig. 8**). **Fig. 9** had too few observations in height groups 150–159 cm (n=1), 160–169 cm (n=4) and >=190 cm (n=16). Therefore conclusions could not be drawn about them. There was a tendency for males in height group 170–179 cm compared to 180-189 cm to have an increased number of MT and LT, but there were too few observations to have a significant value.

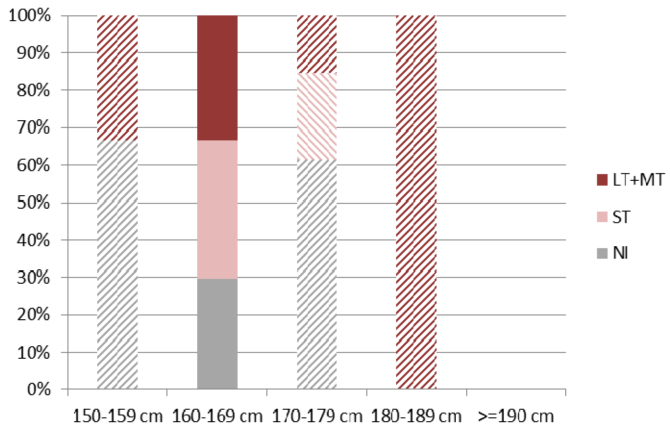


**Fig. 8**. The duration of neck pain symptoms, FEMALE distributed in height groups. (n=44)

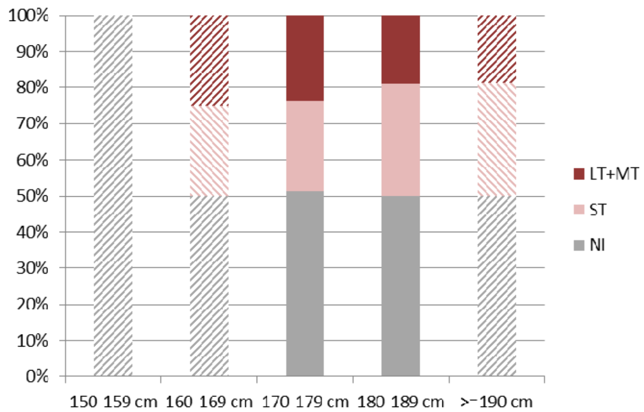


**Fig. 9.** The duration of neck pain symptoms, MALE distributed in height groups. (n=167)

***Driver: BMI and Gender***

BMI were divided into three different groups, persons of average weight (18.5 - <25), overweight persons (25 - >30) and obese persons (>=30). None of the persons in the surveys were underweight. There were approximately 30 percent females of average weight in the group who had medium and long term neck pain symptoms, compared to males in the same BMI group who had a 10 percent lower value. However, this is not significant (p=.310). Male-groups 18.5- >25 and 25- <30 have no statistical significance (p=1.000).

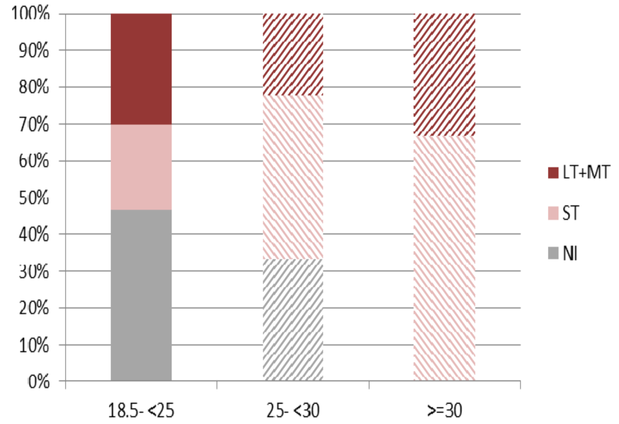


**Fig. 10**. The duration of neck pain symptoms, FEMALE distributed in BMI groups. (n=42)

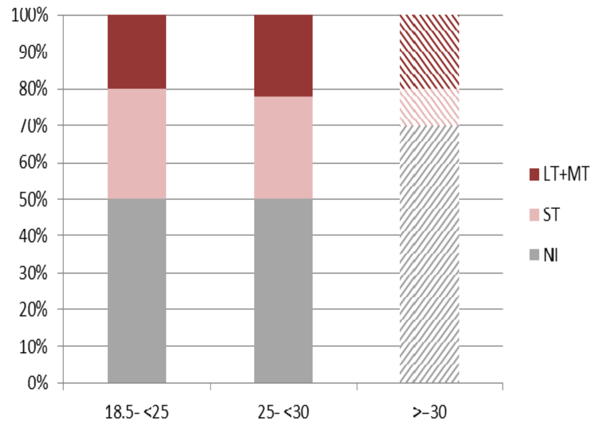


**Fig. 11.** The duration of neck pain symptoms, MALE distributed in BMI groups. (n=166)

### *Driver: Collision Action and Gender*

Collision Action was divided into three groups; if the vehicle was braking, driving or standing still. These results are based on cases from Survey 2. In the Braking group, females reported more LT and MT than males and it proved significant (p=.003) (**Fig. 12**). With regards to the Driving group, almost all were uninjured irrespective of gender; however this group comprised too few females in this group. For the Collision Action Stationary group, there were minor differences between the genders, not significant (p=0.549) (**Fig. 12**).

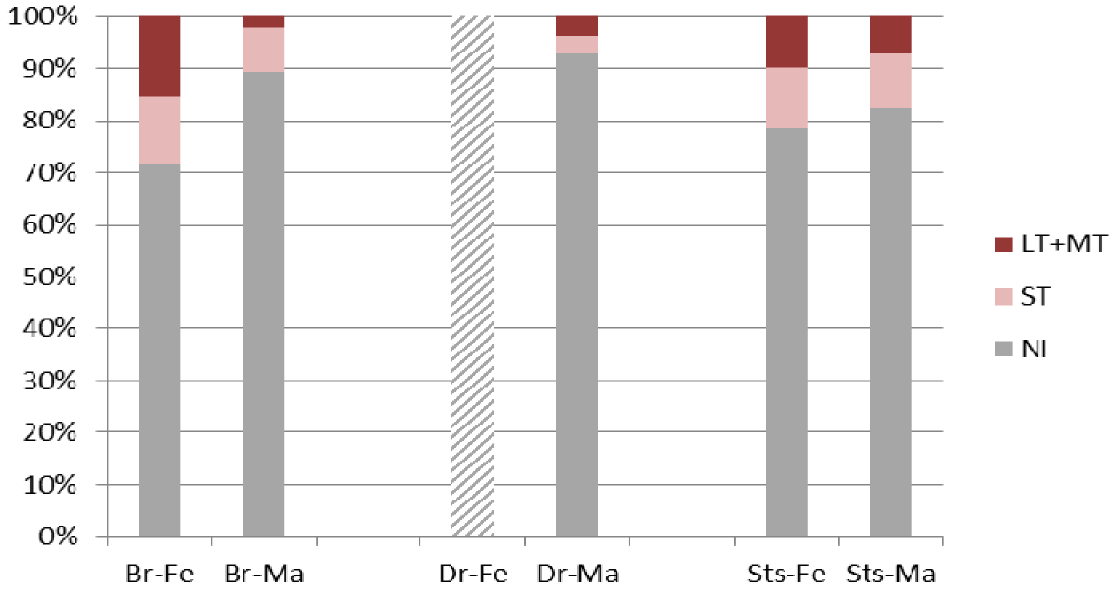


**Fig. 12**. The duration of neck pain symptoms, gender distributed in Collision Action (Br-Fe = Braking, female; Br-Ma= Braking, male; Dr-Fe= Driving, female; Dr-Ma= Driving, male; Sts-Fe= Standing still, female; Sts-Ma= Standing still, male). ($n_{Br}$=188, $n_{Dr}$=35, $n_{Sts}$=274)

### *Driver: Collision Site*

The Collision Site group was divided into seven main groups; Traffic light, Queue, Zebra crossing, Give way, Roundabout, Give way roundabout, Stop sign and Other. These results are based on cases from Survey 2. The most common place for collisions to occur was at Traffic lights (22 percent), secondly Queues (19 percent), thirdly Zebra crossings (17 percent) and in fourth place at Give way signs (16 percent) (**Fig. 13**).

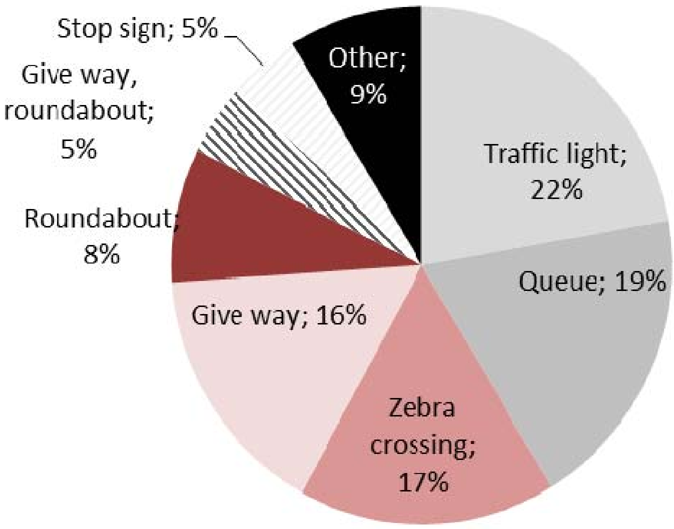


**Fig. 13**. Most common places for collisions to occur. (n=263)

In the Roundabout group, the drivers had the highest risk (13 percent) of sustaining LT and MT. The lowest risk for drivers of sustaining LT and MT was at the Give way and Stop signs out of the Collision Site groups. Of the four major groups, Give way was the only group with no LT or MT cases (**Fig. 14**). Significant difference were found between the Give way and Roundabout groups, p=.039.

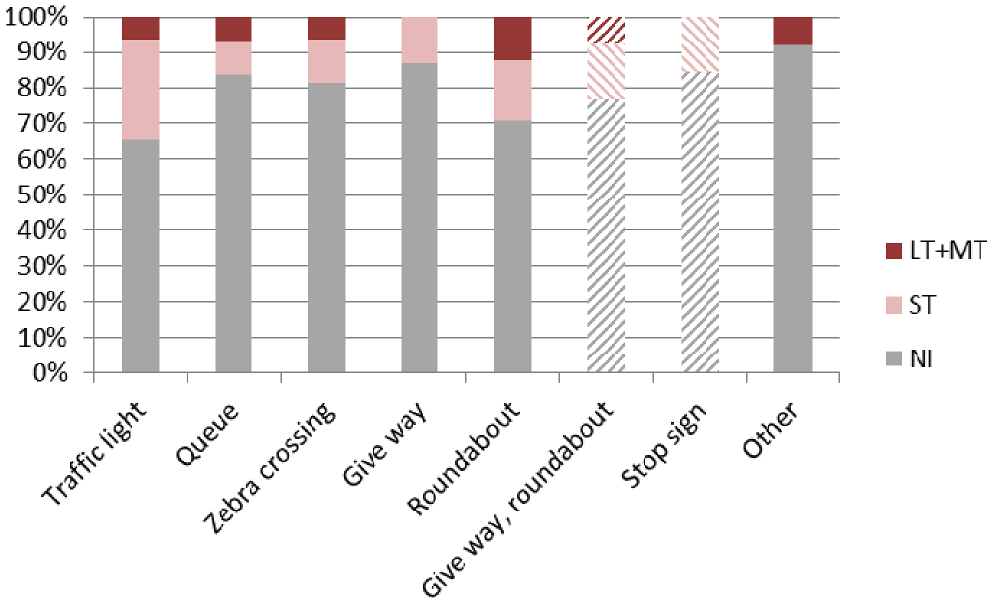


**Fig. 14**. The duration of neck pain symptoms and Collision Site. (n=228)

## IV. DISCUSSION

Male passengers seated in the front seat tended to have a greater risk of sustaining LT+MT neck pain symptoms (15 percent) compared to male drivers (6 percent), while the females had a similar risk in either front seat (drivers: 10 percent, front seat passengers: 12 percent) (**Fig. 2**). Greater differences between the two front seats were recorded for the ST neck pain symptoms for the males as well as for the females (drivers: ~10 percent, front seat passengers: ~30 percent). The result from this study is supported by earlier studies [13][20], however, other studies have reported that the whiplash injury risk is greater in the driver seat compared to the front passenger seat [21–22]. The long-term whiplash injury risk was reported to be approximately twice as high for female drivers compared to female front seat passengers in rear impacts [17] (**Fig. 1**). Factors that may contribute to these differences could be seated posture and grip of the steering wheel. Little is known about the influence of the steering wheel with regard to the dynamic response of the occupant during the seatback interaction and/or during the rebound in rear impacts. In frontal impacts, an increased risk of whiplash injury symptoms was reported for occupants tightly gripping the steering wheel or straightening their arms [25]. In addition, it may be that different anti-whiplash systems and seat designs influence the distribution of risk between the passenger and driver position differently. Furthermore, in-depth comparison between studies in the literature might show differences in distribution of, for example, impact severity which could influence the results.

The LT+MT neck pain symptoms risk tended (not statistically significant) to be greater in vehicles fitted with a tow bar compared to vehicles lacking a tow bar (**Fig. 3**). This tendency was more pronounced for the female drivers (12 percent versus 7 percent) compared to the male drivers (8 percent versus 5 percent). Similar results were reported by [26], reporting a 22 percent higher long term whiplash injury risk in rear impacts sustained in cars fitted with a towing hook compared to cars without a towing hook (same car model) [26]; the data were however not separated for females and males. The presence of a towing hook may increase the severity of the crash pulse, which has been shown to influence the injury risk. [7][27].

For female drivers, the LT+MT neck pain symptoms risk were significant higher than for the males for the age group 35-44 years, while for the male drivers the risk was significantly higher than for the females in the age group >=65 years (**Fig. 4**). At older ages the risks were lower for both females and males. Similar trends have been reported in earlier studies, indicating that the whiplash injury risk seems to peak at younger/middle ages and decrease at older ages [15][22][28]. The reason may possibly be that increasing age is associated with increasing stiffness of the neck. For example, [29] found that the Active Range of Motion of neck extension was greatest for young people and decreasing as the age increased.

The LT+MT neck pain symptoms tended to be greater for either very light or for very heavy drivers; this tendency was noted for both males and females (**Fig. 5–6**). In earlier studies the weight of the occupants appeared to have minor/no correlation with the whiplash injury risk [15][23][30]. The LT+MT neck pain symptoms tended to decrease for increasing height of both male and female drivers (**Fig. 7–8**). These results deviate from earlier studies, reporting generally increasing trends for increasing height for males and females [10][15][21–22]. In addition, [25] showed an increasing trend of risk for increasing height for male occupants, while for female occupants the risk was approximately the same for all the selected height intervals. The influence of height may be different for different types of seats. The main contributing factors related to height and occurrence of neck pain symptoms are still to be established.

The LT+MT neck pain symptoms were considerably less for male drivers (2 percent) compared to female drivers (15 percent) if the vehicle was impacted while braking (**Fig. 9**). Applying the brakes of the vehicle may, due to the momentum of the upper body, have resulted in the head restraint (HR) distance being increased at the time of the impact. For this reason it is possible that the females were affected to a greater extent by the braking event compared to the males. Based on volunteer tests, it was found that female volunteers subjected to an unexpected braking event seemed to experience a longer forward motion than males of the same size [31]. Furthermore, males and females of the same seated stature appeared to have a different motion pattern in driver as well as passenger positions. The forward motion of the male volunteers seemed to follow the deceleration pulse, with only a short time at the turning point, whereas the females stayed in the most forward position for a longer period, until the brake released [31]. A long HR distance is associated with increased whiplash injury risk [4][24–25][28][32–33]. Moreover, [28] concluded that “Not only are women more likely than men to suffer neck injuries in rear impacts, but they are affected more by changes in head restraint positioning”. In addition, [34] found that improved head restraint geometry reduces the whiplash injury risk to a greater extent for females than for males.

The LT+MT neck pain symptoms for drivers tended to be greater in roundabouts compared to traffic lights. The reason may be that drivers, to a greater degree, may be out of position and have their heads’ turned at the time of the impact in a roundabout compared to at a traffic light. The question may be raised whether the roundabout is an environment with higher risk compared to traffic lights with regards to long term neck pain symptoms.

The low number of observations in this study limited the posibilities to draw conclusions for several of the subgroups. A larger dataset would be required in order to establish whether trends seen in this study are stastistically significant findings. In particular, it was not possible to relatethe influence of impact severity any particular subgroup. It may be that some collision sites are designed such that more severe crashes in terms of neck pains symptoms, are generated at these sites. A larger dataset may thus give new insights into how the road system could be improved. Furthermore, the results of this study indicate the need for improved understanding of the differences between driver and passenger performance in different driving scenarios. In addition, how the head to head restraint distance is influenced during braking and how it affects the injury outcome should be studied for both males and females.

## V. CONLUSIONS

The results show that passengers are more likely to suffer neck pain symptoms than drivers in the collisions that occurred in the same make of a particular car. No significant differences in risk related to age, gender weight, and height could be identified, except for:

- Females aged 35-44 had higher risk to have long and medium term neck pain symptoms than males in the same group of age.
- Males aged >=65 had higher risk to have long and medium term neck pain symptoms than males aged 35-44.
- Females in group "Braking" had higher risk of any type of neck pain symptoms than males.

Regarding the collision site, rear end collisions that occurred at traffic lights most often resulted in neck pain symptoms. Collisions in roundabouts was the most common reason for mid and long term neck pain symptoms.

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## VIII. APPENDIX

$P_{x, y\text{-}z}$, where P=p-value and x=within group, y-z=test between variable y and z. Fe=Female, Ma=Male, Dr=Driver, '35-44'=35-44 years, etc.

**TABLE A-I** STATISTICS FOR FIG. 2.

| | Drivers | | | Passengers front-seat | | |
|---|---|---|---|---|---|---|
| | Females (n) | Males (n) | Total (n) | Females (n) | Males (n) | Total (n) |
| NI | 108 | 495 | 603 | 34 | 15 | 49 |
| ST | 13 | 50 | 63 | 19 | 8 | 27 |
| LT+MT | 13 | 36 | 49 | 7 | 4 | 11 |

$P_{Fe, Dr-Pa}$=.799, $P_{Ma, Dr-Pa}$=.094, $P_{Dr, Fe-Ma}$=.182, $P_{Pa, Fe-Ma}$=.733

**TABLE A-II** STATISTICS FOR FIG. 3 (ONLY DRIVERS).

| | Tow bar YES | | | Tow bar NO | | |
|---|---|---|---|---|---|---|
| | Females (n) | Males (n) | Total (n) | Females (n) | Males (n) | Total (n) |
| NI | 59 | 279 | 338 | 47 | 200 | 247 |
| ST | 8 | 25 | 33 | 5 | 24 | 29 |
| LT+MT | 9 | 26 | 35 | 4 | 13 | 17 |

$P_{Fe, Yes-No}$=.556, $P_{Ma, Yes-No}$=.490, $P_{Yes, Fe-Ma}$=.163, $P_{No, Fe-Ma}$=.750

**TABLE A-III** STATISTICS FOR FIG 4-5.

| | Female | | | | Male | | | |
|---|---|---|---|---|---|---|---|---|
| | LT+MT (n) | ST (n) | NI (n) | Tot (n) | LT+MT (n) | ST (n) | NI (n) | Tot (n) |
| 16-24 years | 0 | 0 | 6 | 6 | 2 | 2 | 11 | 15 |
| 25-34 years | 0 | 2 | 16 | 18 | 4 | 7 | 71 | 82 |
| 35-44 years | 9 | 5 | 33 | 47 | 6 | 18 | 136 | 160 |
| 45-54 years | 2 | 4 | 29 | 35 | 12 | 12 | 122 | 146 |
| 55-64 years | 2 | 2 | 15 | 19 | 7 | 10 | 108 | 125 |
| >=65 years | 0 | 0 | 2 | 2 | 4 | 1 | 24 | 29 |
| Total | 13 | 13 | 101 | 127 | 35 | 50 | 472 | 557 |

$P_{'35\text{-}44', Fe-Ma}$=.001, $P_{'45\text{-}54', Fe-Ma}$=1.000, $P_{Fe, '35\text{-}44'\text{-}'45\text{-}54'}$=.105, $P_{Ma, '25\text{-}34'\text{-}'35\text{-}44'}$=.737, $P_{Ma, '25\text{-}34'\text{-}'45\text{-}54'}$=.426, $P_{Ma, '25\text{-}34'\text{-}'55\text{-}64'}$=1.000, $P_{Ma, '25\text{-}34'\text{-}'>=65'}$=.203, $P_{Ma, '35\text{-}44'\text{-}'45\text{-}54'}$=.146, $P_{Ma, '35\text{-}44'\text{-}'55\text{-}64'}$=.570, $P_{Ma, '35\text{-}44'\text{-}'>=65'}$=.049, $P_{Ma, '45\text{-}54'\text{-}'55\text{-}64'}$=.478, $P_{Ma, '45\text{-}54'\text{-}'>=65'}$=.309, $P_{Ma, '55\text{-}64'\text{-}'>=65'}$=.221

**TABLE A-IV** STATISTICS FOR FIG. 6–7.

| | | Female | | | | Male | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | LT+MT (n) | ST (n) | NI (n) | Tot (n) | LT+MT (n) | ST (n) | NI (n) | Tot (n) |
| 50-59 | kg | 4 | 2 | 5 | 11 | - | - | - | - |
| 60-69 | kg | 6 | 5 | 9 | 20 | 0 | 2 | 4 | 6 |
| 70-79 | kg | 1 | 2 | 1 | 4 | 16 | 17 | 26 | 59 |
| 80-89 | kg | 0 | 4 | 1 | 5 | 10 | 15 | 33 | 58 |
| 90-99 | kg | 1 | 0 | 1 | 2 | 5 | 9 | 13 | 27 |
| 100-109 | kg | - | - | - | - | 4 | 3 | 5 | 12 |
| >=110 | kg | - | - | - | - | 0 | 1 | 4 | 5 |
| Total | | 12 | 13 | 17 | 42 | 35 | 47 | 85 | 167 |

$P_{Ma, '70\text{-}79'\text{-}'80\text{-}89'}$=.267, $P_{Ma, '70\text{-}79'\text{-}'90\text{-}99'}$=.433, $P_{Ma, '80\text{-}89'\text{-}'90\text{-}99'}$=1.000

**TABLE A-V** STATISTICS FOR FIG. 8–9.

| | | Female | | | | Male | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | LT+MT (n) | ST (n) | NI (n) | Tot (n) | LT+MT(n) | ST (n) | NI (n) | Tot (n) |
| 150-159 | cm | 1 | 0 | 2 | 3 | 0 | 0 | 1 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 160-169 | cm | 9 | 10 | 8 | 27 | 1 | 1 | 2 | 4 |
| 170-179 | cm | 2 | 3 | 8 | 13 | 17 | 18 | 37 | 72 |
| 180-189 | cm | 1 | 0 | 0 | 1 | 14 | 23 | 37 | 74 |
| >=190 | cm | - | - | - | - | 3 | 5 | 8 | 16 |
| Total | | 13 | 13 | 18 | 44 | 35 | 47 | 85 | 167 |

$P_{Ma,\ '170\text{-}179'\text{-}'180\text{-}189'}$=.547

**TABLE A-VI** STATISTICS FOR FIG. 10-11.

| | Female | | | | Male | | | |
|---|---|---|---|---|---|---|---|---|
| BMI | LT+MT | ST | NI | Tot (n) | LT+MT(n) | ST (n) | NI (n) | Tot (n) |
| <18.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18.5- <25 | 9 | 7 | 14 | 30 | 16 | 24 | 40 | 80 |
| 25- <30 | 2 | 4 | 3 | 9 | 17 | 21 | 38 | 76 |
| >=30 | 1 | 2 | 0 | 3 | 2 | 1 | 7 | 10 |
| Total | 12 | 13 | 17 | 42 | 35 | 46 | 85 | 166 |

$P_{Ma,\ '18.5\text{-}<25'\text{-}'25\text{-}<30'}$=1.000, $P_{'18.5\text{-}<25',\ Fe\text{-}Ma}$=.310

**TABLE A-VII** STATISTICS FOR FIG. 12.

| | Braking | | Driving | | Standing still | |
|---|---|---|---|---|---|---|
| | Br-Fe (n) | Br-Ma (n) | Dr-Fe (n) | Dr-Ma (n) | Sts-Fe (n) | Sts-Ma (n) |
| LT+MT | 6 | 3 | 0 | 1 | 5 | 16 |
| ST | 5 | 13 | 0 | 1 | 6 | 23 |
| NI | 28 | 133 | 7 | 26 | 40 | 184 |
| TOTAL | 39 | 149 | 7 | 28 | 51 | 223 |

$P_{Br,\ Ma\text{-}Fe}$=.003, $P_{Sts,\ Fe\text{-}Ma}$=.549

**TABLE A-VIII** STATISTICS FOR FIG. 13-14

| | Traffic light (n) | Queue (n) | Zebra crossing (n) | Give way (n) | Roundabout (n) | Give way, roundabout (n) | Stop sign (n) | Other (n) | Total (n) |
|---|---|---|---|---|---|---|---|---|---|
| LT+MT | 4 | 4 | 3 | 0 | 3 | 1 | 0 | 2 | 17 |
| ST | 18 | 5 | 6 | 6 | 4 | 2 | 2 | 0 | 43 |
| NI | 42 | 46 | 39 | 40 | 17 | 10 | 11 | 23 | 228 |

$P_{Tr\ Li\text{-}Queue}$=1.000, $P_{Tr\ Li\text{-}Ze\ Cr}$=1.000, $P_{Tr\ Li\text{-}Gi\ Wa}$=.258, $P_{Tr\ Li\text{-}Round}$=.345, $P_{Queue\text{-}Ze\ Cr}$=1.000, $P_{Queue\text{-}Gi\ Wa}$=.244, $P_{Queue\text{-}Round}$=.380, $P_{Ze\ Cr\text{-}Gi\ Wa}$=.496, $P_{Ze\ Cr\text{-}Round}$=.319, $P_{Gi\ Wa\text{-}Round}$=.039