Industrial Health 2010, **48**, 164–170 **Original Article**

Commuting Accidents in the German Chemical Industry

Kirsten Isabel ZEPF[1]*, Stephan LETZEL[1], Susanne VOELTER-MAHLKNECHT[1], Ulrich WRIEDE[2], Britta HUSEMANN[1] and Luis Carlos ESCOBAR PINZÓN[1]

[1]Institute of Occupational, Social and Environmental Medicine, Johannes Gutenberg University Mainz, Obere Zahlbacher Str. 67, 55131 Mainz, Germany

[2]Distribution Safety - Classification, Dangerous Goods Information Systems, BASF - The Chemical Company, Ludwigshafen, Germany

Received May 22, 2009 and accepted August 7, 2009

Abstract: Due to accident severity and the extent of claim payments commuting accidents are a significant expense factor in the German industry. Therefore the aim of the present study was the identification of risk factors for commuting accidents in a German chemical company. A retrospective analysis of commuting accidents recorded between 1990 and 2003 was conducted in a major chemical company in Germany. A logistic regression-model was calculated in order to determine factors influencing the duration of work inability as a result of commuting accidents. The analysed data included 5,484 employees with commuting accidents. Cars (33.1%) and bicycles (30.5%) were the most common types of vehicles used by commuters who had an accident. The highest number of commuting accidents was observed in the age group under 26 yr. Accidents on the route from the work site to the worker's residence were less frequently observed, but they caused longer periods of work inability than accidents on the way to the work site. The longest periods of work inability were found in the groups of motorcyclists and older employees. The present study identifies specific groups at risk for commuting accidents. The data of the present investigation also underline the need for developing group specific prevention strategies.

Key words: Road safety, Commuting accidents, Risk factors, Work inability, Prevention strategies

Introduction

Work-related accidents include two types of accidents: commuting accidents and accidents occurring during the course of work. Commuting accidents are defined as accidents happening on the route between the worker's residence and the work site as well as well as on the route from the work site to the residence. In Germany, employees injured in commuting accidents are indemnified by the employer's liability insurance association in a comparable manner as with other work-related injuries. Accidents that lead to work inability of more than 3 d or even cause death are registered at the appropriate Accident Prevention and Insurance Association covered by the employer. These events are listed as reportable accidents in the relevant German accident statistics. Commuting accidents constitute large expenses for insurance companies. This is mainly due to their increasing number and the resulting claim payments. Because of wage continuation in the case of illness as well as direct and indirect costs related to accident injuries these costs cause a significant burden for the industry. Not only the proportion of commuting accidents related to the total number of accidents, but also the amount of new accident benefits underline the relevance of commuting accidents for the health of employees and the financial burden. According to the annual report of the DGU[1)] (German employer's liability insurance association) 167,067 reportable commuting accidents took place in Germany in the year 2007, and 6,170 accident benefits were paid.

The consequences of these work-related accidents for

*To whom correspondence should be addressed.
E-mail: loefflek@uni-mainz.de

the persons involved as well as for the economy must be considered crucial[2]. A wealth of empirical studies on different contextual risk factors for commuting accidents is currently available, and some of these studies need to be mentioned within this context. Some authors found that young people in particular have a higher risk to be involved in commuting accidents compared with older people, with this increased risk reaching statistical significance when these young employees are under 25 yr of age[3, 4]. With respect to gender as a potential risk factor regarding commuting accidents the data of Salminen[5] indicated that women had a 1.4 times higher frequency of commuting accidents compared to men. Commuting accidents take place more frequently under environmental conditions of darkness, snow and rain, in particular in winter time[6]. Harrison *et al*.[7] showed within their analysis of 1,544 lethal work and commuting accidents between 1982 and 1984 in Australia that most of the lethal commuting accidents happened in the early morning and late evening hours. Concentrating on the means of transportation most of the studies agree that motorcyclists and pedestrians have a higher risk for commuting accidents with severe and often lethal consequences than any other mean of transportation[8].

However, only few authors have focused on sociodemographic risk factors in combination with occupational risk factors related to commuting accidents. There is also a lack of studies which draw attention to the consequences of these accidents in terms of work inability. The present work presents data related to the frequency of commuting accidents in a German chemical company concentrating on specific risk factors and on the duration of work inability as a major consequence of these accidents.

Subjects and Methods

The analysed data included all casualties of commuting accidents within a major chemical company in Germany between 1990 and 2003. The following variables associated with the registered commuting accidents were examined:

1. Socio demographic data: age; gender.
2. Occupational data: working-time model (day work, rotating shift work, part-time); professional position (blue-collar worker, white-collar employee, apprentice)
3. Accident specific data: time, day and month of occurrence, direction of the route (route to work, route from work site to employee's residence); means of transportation (pedestrian, bicycle, car, motorcycle, public transportation).
4. Duration of work inability

With respect to the mentioned variables concerning age, gender and occupation, the data of the accident sample was analysed with respect to the company's workforce as the reference population. The comparison with this reference population permitted us to determine groups with a high accident risk. Rates of accident frequency are presented as accidents per year and per 1,000 employees. Accident rates and the absolute frequency are presented in cross-classified tables.

Variables were explored concerning their influence on the duration of work inability in a multivariate cumulative logistic regression model[9]. The response variable was the duration of work inability as indexed by categories (0, 1–3, 4–14, 15–28, and 29 or more days). Multivariate adjusted as well as crude Odds Ratios and their 95% confidence intervals are presented as risk estimates. All variables described above were regarded as potential confounders and were analysed within the model. In addition, potential interactions between age and gender, working-time model and age, means of transport and age, means of transport and gender, means of transport and time of day, and the direction of route and time of day were added to the model after backward selection (level of significance was set and kept at $p<0.05$). The data were analysed by using SAS software.

Results

Over the time period between 1990 and 2003, 5,484 commuting accidents were registered by the company. Table 1 illustrates the rates of commuting accidents per 1,000 employees by year of accident in the chemical com-

Table 1. Rates of commuting accidents by year of incidence

	Rate per 1,000 employees/insurants per year	
yr	Chemical company	Insurance association of chemical industry
1990	6.1	5.9
1991	5.2	6.1
1992	4.3	5.9
1993	4.4	5.8
1994	4.0	5.9
1995	4.4	5.5
1996	4.4	5.8
1997	4.5	5.9
1998	4.2	5.5
1999	4.1	5.6
2000	4.1	5.8
2001	3.9	5.8
2002	4.0	5.7
2003	4.1	5.7

pany along with the rates of commuting accidents per 1,000 insurants counted by the German insurance association of chemical industry. The rates of commuting accidents registered by the company were lower than the rates of commuting accidents per 1,000 insurants as observed by the insurance association in the analysed time period between 1990 and 2003.

Socio demographic and occupational variables

1) Age and sex

Table 2 displays the number and rates of commuting accidents for males and females and different age groups. The rate of commuting accidents was higher in the age group under 25 yr (13.3 per 1,000 employees and per year) compared with the age group from 26 to 45 yr (8.1) and the age group from 46 to 65 yr (7.0). Females (9.9) had a slightly higher rate in experiencing commuting accidents compared to men (8.2).

Separate analyses were conducted for males and females for five age groups (under 25 yr, 26–35 yr, 36–45 yr, 46–55 yr, 56 yr and above). No significant differences in the frequency of commuting accidents for males and females depending on the age group were detected, with the only exemption of higher rates of commuting accidents in female subjects in the age group under 25 yr compared to men in the same respective age group (Table 3).

2) Working-time model and occupation

Table 4 presents the rates of commuting accidents for different working-time models and occupational groups. There were no significant differences regarding the working time model, except for a smaller accident rate for employees working part-time which needs to be seen in the context of less working days in this particular group. Focusing on occupational groups the rates of commuting accidents for blue collar workers (9.9) was moderately higher than for white collar employees (8.2). In comparison to these two groups apprentices had an increasing rate of commuting accidents (13.4). This rate was about the same as the rate for employees under 25 yr, reflecting the age group most of the company's apprentices belong to.

Table 2. Age and gender specific rates of commuting accidents

	Age				Sex	
	General work population	Under 25 yr	26–45 yr	46–65 yr	Male	Female
Average number of employees in the chemical company	46,286	6,394	24,689	15,202	39,209	7,077
Commuting accidents 1990–2003	5,484	1,188	2,794	1,496	4,505	979
Average number of annual commuting accidents	391.7	84.9	199.6	106.9	321.8	69.9
Average number of annual commuting accidents per 1,000 employees	8.5	13.3	8.1	7.0	8.2	9.9

Table 3. Age and gender specific rates of commuting accidents

	Age group				
Sex	Under 25 yr of age	26–35 yr	36–45 yr	46–55 yr	56 yr and older
Male	19.3%	27.9%	24.7%	20.4%	7.7%
Female	32.7%	25.8%	17.7%	17.6%	6.2%

Table 4. Rates of commuting accidents by working time models and occupational major groups

	Working time model				Occupational group		
	General work population	Day work	Rotating shift work	Part-time	Blue collar worker	White collar employees	Apprentices
Number of employees in the company	46,286	31,259	12,858	2,169	7,077	39,209	2,879
Commuting accidents 1990–2003	5,484	3,879	1,434	171	979	4,505	541
Average number of annual commuting accidents	391.7	277.1	102.4	12.2	69.9	321.8	38.6
Average number of annual commuting accidents per 1,000 employees	8.5	8.9	8.0	5.6	9.9	8.2	13.4

Table 5. Means of transport used by the accident sample and by the company's work population in 1998

	Frequency (%)	
Means of transport	Commuting accidents (1990–2003) (N=5,485)	Means of transport used by workforce*
Pedestrian	20.4%	1.0%
Bicycle	30.5%	12.0%
Car	33.1%	69.3%
Motorcycle	12.9%	2.4%
Public transport (bus, train, tram)	2.0%	15.2%

*1998 survey of means of transport used by the company's workforce in Germany.

Table 6. Means of transport by age and gender

	Age group					Sex	
Means of transport	Under 25 yr	26–35 yr	36–45 yr	46–55 yr	56 yr and older	Male	Female
Pedestrian	17.5%	16.1%	19.1%	25.1%	31.5%	17.7%	30.7%
Bicyclist	18.9%	30.0%	32.2%	38.0%	40.4%	33.7%	15.7%
Car	45.7%	37.9%	29.5%	23.2%	16.9%	30.6%	44.8%
Motorcyclist	12.5%	12.2%	14.9%	9.6%	5.3%	13.7%	3.2%
Public transport	3.2%	1.0%	1.4%	2.3%	2.9%	1.7%	3.2%
Others	2.1%	2.8%	3.0%	1.8%	2.9%	5.0%	2.3%

Accident specific variables

1) Time of occurrence and direction of route

Regular commuting hours generated two accident peaks depending on general work rhythms. One peak was in the morning hours between 6:00 a.m. and 8:00 a.m., the other peak appeared in the late afternoon between 5:00 p.m. and 7:00 p.m. On Monday and Tuesday most accidents took place (20.7% each day). Just 6.9% of the accidents happened on Saturdays and Sundays. There was a higher proportion of commuting accidents during winter time from November to March compared to summer time (May to September). In terms of the direction of the route the number of accidents taking place on the way from the residence to the work site (60.8%) was much higher compared to the number of accidents happening on the way from the work site to the residence (39.2%). A descriptive analysis of the accident sites indicated that a major proportion of the commuting accidents (n=1.452) took place within a radius of 500 metres from the company. Most of these were car accidents and bicycle accidents.

2) Means of transport

Most commuting accidents happened while commuting by car (33.1%), followed by bicycle accidents (30.5%). Only 2.0% of commuting accidents took place while commuting on public transportation. A rough estimate of the accident rate concerning means of transport was possible by comparing the actual accident data with data from a survey conducted in 1998 examining the means of transport used by the company's workforce. Table 5 displays the relative frequency of commuting accidents by means of transport and the distribution of means of transport in the company's work population in 1998. A higher proportion of commuting accidents involving pedestrians, bicyclists and motorcyclists was detected.

The distribution of means of transport by age and gender is presented in Table 6. Females more often had an accident while commuting by car and as a pedestrian compared to males. The frequency of bicycle accidents and motorcycle accidents was higher for males than for females. Most of the persons under 25 yr were involved in a car accident, whereas most of the persons in the age group between 36 and 65 yr had a bicycle accident.

Work inability

Thirty-three point eight persent of the commuting accidents did not result in work inability. 12.6% of the commuting accidents led to work inability of 1 to 3 d. In 24.2% of the cases a commuting accident resulted in work inability for a period of 4 to 14 d. 14% of the casualties were unable to work for 15 to 28 d. 15.4% of the commuting accidents led to work inability of more than 29 d. Ten people were killed in an accident. The interaction between means of transport and age and the interaction between means of transport and time of day were included in the multivariate model after backward selection. The crude and adjusted Odds Ratios are illustrated in

Table 7 for the variables with no interaction in the multivariate model. No differences between males and females in the duration of work inability were found after adjustment for the other variables in the model. While longer work inabilities were recorded for employees working in rotating shift in comparison to employees working in flexible time (OR_{crude}=1.6), this difference could not be observed after adjustment (OR_{adj}=1.1). Regarding the area of operation adjusted for the other variables only employees working in research had longer work inabilities than employees working in the administration (OR_{adj}=1.4). A longer period of work inability was still present for blue collar workers after adjustment in comparison to white collar workers (OR_{adj}=1.9). Accidents on the route from the work site to the worker's residence more often resulted in a longer work inability than accidents on the way to work (OR_{adj}=1.28).

A shorter period of work inability in comparison to car drivers (Table 8) was observed for bicyclists as well as for employees aged under 25 yr (OR_{adj}=0.6), and for employees aged between 26 and 45 yr (OR_{adj}=0.7). No difference between car drivers and bicyclists existed for employees at the age of 46 yr and beyond. In contrast there was no difference between car drivers and motorcyclists in the youngest age group, but there were longer work inabilities in the age group between 26 and 45 yr (OR_{adj}=1.7). In particular, this relationship was observed for older employees at the age of 46 yr and beyond (OR_{adj}=3.2). Shorter work inability was observed for commuting accidents with public transport (OR_{crude}=0.7) than for car drivers. The difference was smaller after adjustment for the other variables. An increase in work inability depending on increasing age was observed over all means of transport (data not shown).

Longer work inability was observed when the accidents happened at night (7 p.m. to 7 a.m.) (OR_{crude}=1.3). This was basically due to car drivers (OR_{adj}=1.3) and bicyclists (OR_{adj}=1.3), with each of these two groups having a

Table 7. Odds Ratio estimates for the risk of longer work inability

Variable	Category	OR [95%CI], crude	OR [95%CI], adjusted*[2]
Sex	Male	1	1
	Female	0.83 [0.73–0.94]*	1.08 [0.93–1.26]
Age	Up to 25 yr	0.75 [0.66–0.85]*	*[3]
	26–45 yr	1	*[3]
	46 yr and older	1.14 [1.02–1.28]*	*[3]
Working-time model	Flexible time	1	1
	Part-time	1.32 [1.00–1.74]	1.12 [0.84–1.48]
	Rotating shift	1.56 [1.40–1.75]*	1.08 [0.92–1.27]
Area of operations	Administration	1	1
	Research	1.55 [1.29–1.86]*	1.42 [1.18–1.72]*
	Reproduction	1.90 [1.62–2.23]*	1.16 [0.95–1.42]
	Dispatch	1.77 [1.34–2.34]*	1.10 [0.82–1.48]
	Workshop	1.47 [1.26–1.72]*	1.12 [0.93–1.34]
Occupational group	White collar worker	1	1
	Apprentice	0.70 [0.59–0.84]*	0.83 [0.66–1.04]
	Blue collar worker	1.85 [1.67–2.05]*	1.86 [1.63–2.11]*
Time of day	7 a.m.–7.p.m	1	*[3]
	7 p.m.–7.a.m	1.25 [1.13–1.38]*	*[3]
Direction of route	Route to work	1	1
	Route going home	1.17 [1.06–1.29]*	1.28 [1.15–1.42]*
Means of transportation	Car	1	*[3]
	Bicycle	0.80 [0.71–0.90]*	*[3]
	Pedestrian	1.07 [0.93–1.22]	*[3]
	Motorcycle	1.46 [1.24–1.72]*	*[3]
	Public transport	0.87 [0.61–1.23]	*[3]
	Others	0.70 [0.50–0.98]*	*[3]

*Confidence interval does not include 1. Values above 1 indicate groups with a tendency for longer work inability than the reference category, values smaller 1 indicate a shorter period of work inability. *[2]Adjusted for sex, age, working-time model, area of operations, occupational group, time of day, weekday, month, direction of route, means of transportation, the interaction between means of transportation and age and the interaction between means of transportation and time of day. *[3]given in more detail in Tables 8 and 9.

Table 8. Odds Ratio estimates for the risk of longer work inability in regard to means of transportation by age group

	OR [95%CI], adjusted*[2]		
Age category	Under 25 yr	26–45 yr	46 yr and older
Car	1	1	1
Bicycle	0.63 [0.46–0.86]*	0.70 [0.58–0.85]*	1.06 [0.82–1.38]
Pedestrian	0.94 [0.68–1.30]	1.15 [0.91–1.46]	1.21 [0.90–1.62]
Motorcycle	1.21 [0.84–1.73]	1.73 [1.34–2.23]*	3.18 [2.16–4.71]*
Public transport	0.84 [0.43–1.63]	0.86 [0.44–1.70]	0.97 [0.49–1.91]
Others	0.89 [0.39–2.04]	0.59 [0.34–1.00]	0.72 [0.33–1.55]

*Confidence interval does not include 1. Values above 1 indicate groups with a tendency for longer work inability than the reference category, values smaller 1 indicate a shorter period of work inability. *[2]Adjusted for sex, age, working-time model, area of operations, occupational group, time of day, weekday, month, direction of route, means of transportation, the interaction between means of transportation.

Table 9. Odds Ratio estimates for the risk of longer work inability in regard to time of day by means of transportation

	OR [95%CI], adjusted*[2]	
	7 a.m.–7 p.m	7 p.m.–7 a.m.
Car	1	1.34 [1.12–1.61]*
Bicycle	1	1.29 [1.07–1.56]*
Pedestrian	1	1.12 [0.90–1.40]
Motorcycle	1	0.76 [0.57–1.02]
Public transport	1	1.66 [0.82–3.37]
Others	1	1.25 [0.64–2.44]

*Confidence interval does not include 1. Values above 1 indicate groups with a tendency for longer work inability than the reference category, values smaller 1 indicate a shorter period of work inability. *[2]Adjusted for sex, age, working-time model, area of operations, occupational group, time of day, weekday, month, direction of route, means of transportation, the interaction between means of transportation.

longer period of work inability following accidents between 7 p.m. and 7 a.m. in comparison to accidents that happened in the daytime (Table 9).

Discussion

The present study identified groups at risk for commuting accidents. A major finding of this study was that the highest rate of commuting accidents was found in the age group under 25 yr in comparison to other age groups. This finding is in line with other studies showing a high incidence of commuting accidents in the age group under 25 yr[10, 11]. In our study young employees were more often involved in car accidents compared to other means of transport. Consequently, the development of prevention strategies, in particular designed for young car drivers such as traffic safety training programs, could be considered in future research. A further finding was an increase in work inability concerning older employees which could be partly explained by longer regeneration processes in these age groups. However, no higher frequency of commuting accidents was found for older people, but the consequences of these accidents are much more severe in this age group compared to younger people. The rate of commuting accidents for females per 1,000 employees per year did not differ from the rate of commuting accidents for males. Moreover, there was no difference in the duration of work inability as regards males and females. Separate analyses conducted for males and females with respect to different age groups indicated higher rates of commuting accidents for the female subsample in the age group under 25 yr in comparison to males of the same age group. Following this train of thought the findings of the present investigation draw attention to young females under 25 yr constituting a group at risk for commuting accidents, and provide preliminary evidence for a process of risk assimilation between the two genders in this particular age group.

There were no differences found between the rates of commuting accidents concerning the specific working time models. However, the rate of commuting accidents was much higher for apprentices. A longer period of work inability for blue collar workers in comparison to white collar workers was also observed. In the light of these findings it needs to be considered that work inability might be shorter for white collar workers as some injuries might not hinder them from doing their work in an appropriate manner, while blue collar workers would be expected to need more time to recover until they are capable to fulfill their tasks. Most of the accidents took part during winter time, which is in line with the results of previous studies[12]. A closer look to the accident sites showed that a huge part of the accidents happened within near distance from the company. The identification of particular “risk sites” could be subject to further investi-

gations in order to minimize accident risk (for example by certain structural changes).

Focusing on the means of transport not only a high frequency of accidents by car was registered, but also a relatively high number of bicycle, motorcycle and pedestrian accidents were observed. Compared to all other means of transport, commuting by public transport seems to be the safest. The rate of commuting accidents using means of public transport such as bus or train was very low. This finding corresponds with the German accident statistics[13] and other studies about commuting accidents[14] which enhance the low accident risk in public transportation compared to other means of transport. The offer of "job tickets" which allow a reasonable utilisation of public transportation could be mentioned as a possibility of creating a financial incentive for using public transport. Another alternative is the implementation of shift busses allowing the employees to commute at times adjusted to their working shifts. Concerning the groups of motorcyclists and bicyclists the implementation of driver safety training and the encouragement of wearing a bicycle helmet should be taken into consideration.

Our study does not provide precise data on working conditions and specific occupational risk factors, for example time pressure or the experienced stress on the job. Future studies should focus on in depth analyses of cognitive, emotional and behavioural risk factors of commuting accidents, for example experienced work load, working climate etc. in order to provide a wide frame for accident prevention. Such detailed information could not be gathered in the present retrospective study and must be considered as a limitation, with this information being necessary for designing more effective interventional strategies in order to reduce the risk for commuting accidents.

Acknowledgements

We would like to thank M. Budinger for his valuable contributions regarding the statistical analysis. Also, we offer our thanks to management in the company BASF for supporting this study.

References

1) Deutsche Gesetzliche Unfallversicherung. Arbeits- und Wegeunfallgeschehen 2008. http://www.dguv.de/inhalt/zahlen/au_wu/index.jsp. Accessed January 16, 2009 (in German).
2) Miller TR (1997) Estimating the costs of injury to US employers. J Safety Res **28**, 1–3.
3) Campell KL (1991) Fatal accident involvement rates by driver age for large trucks. Accid Anal Prev **23**, 287–95.
4) Charbotel B, Chiron M, Martin JL, Bergret A (2002) Work-related road accidents in France. Eur J Epidemiol **17**, 773–8.
5) Salminen S (2000) Traffic accidents during work and work commuting. Int J Ind Ergon **26**, 75–85.
6) Wanwik PO (2009) Effects of road lighting: an analysis based on Dutch accident statistics 1987–2006. Accid Anal Prev **41**, 123–8.
7) Harrison JE, Mandryk JA, Frommer MS (1993) Work-related road fatalities in Australia, 1982–1984. Accid Anal Prev **25**, 443–51.
8) Geiler M, Musahl HP (2003) Zwischen Wohnung und Arbeitsplatz — Eine Studie zum Arbeitsweg und Wegeunfallgeschehen. Asanger Verlag, Heidelberg (in German).
9) Agresti A (1994) Analysis of ordinal categorical data. John Wiley & Sons, New York.
10) Trimpop R, Kirkcaldy B (1997) Personality predictors of driving accidents. Perso Indiv Diff **23**, 147–52.
11) Turner C, McClure R (2003) Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. Inj Control Saf Promot **10**, 123–30.
12) Mao Y, Zhang J, Robbins G, Clarke K, Lam M, Pickett W (1997) Factors affecting the severity of motor vehicle traffic crashes involving young drivers in Ontario. Inj Prev **3**, 183–9.
13) Statistisches Bundesamt. Unfallgeschehen im Straßenverkehr 2007. http://www.destatis.de. Accessed January 16, 2009 (in German).
14) Doherty ST, Aultman-Hall L, Swaynos J (2000) Commuter cyclist accident patterns in Toronto and Ottawa. J Trans Eng **126**, 21–5.