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Risk of Death from Motor-Vehicle Injury in Brazilian Steelworkers: A Nested Case-Control Study

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Objectives. In a cohort of 21 816 Brazilian steelworkers we found mortality from motor-vehicle injury was twice that in the State population. A nested case-control study was therefore undertaken to investigate possible socio-demographic, medical and occupational risk factors for this increased risk.

Methods. Cases were defined as all steelworkers in the cohort who died of motor-vehicle injury during employment in the period 1977–1992. For each case, four controls were selected at random from workers in the cohort who were employed at the time of death of the case, and who were born in the same year as the case. Data on socio-demographic factors, and medical and occupational histories were obtained from personnel, industrial hygiene and medical records, and the relation of these factors to risk of motor-vehicle injury was analysed using conditional logistic regression.

Results. In a multivariate analysis, the risk of death from motor-vehicle injury was independently associated with being unmarried (odds ratio [OR] compared to married = 3.21, 95% confidence interval [CI] : 1.84–5.59), having a hearing defect (OR = 2.28, 95% CI : 1.10–4.74) and exposure to moderate (OR = 1.71, 95% CI : 1.03–2.83) or high (OR = 2.00, 95% CI : 1.18–3.39) levels of noise at work. The risk of fatal motor-vehicle injury increased with intensity of occupational noise exposure ($P = 0.004$).

Conclusions. The raised risk of motor-vehicle injury death associated with single marital status is likely to relate to selective factors in the types of individual who remain single, and behaviours associated with being unmarried. The raised risks in relation to hearing defects and exposure to occupational noise, factors that do not appear to have been examined previously, imply that occupational noise exposures might be a cause of fatal motor-vehicle accidents outside the workplace. This finding may have widespread public health consequences since high levels of noise in the workplace and occupationally acquired hearing deficits are prevalent in several occupations. Further investigation is needed to confirm the association and its mechanisms and, if it is causal, to develop preventive strategies.

Keywords: case-control, motor-vehicle, mortality, noise

Motor-vehicle injuries are responsible for the majority of fatal unintentional injuries in Western countries and are among the most common causes of avoidable premature death.[1] In developing countries, the number of fatalities per 1000 vehicles is generally 10 to 20 times greater than that in industrialized countries.[2] Brazilian mortality rates from motor-vehicle injuries are higher than those of most countries for which data are available,[3,4] and between 1978 and 1989 crude rates among males rose in most State capitals in the country.[5]

Death rates from motor-vehicle injury in Brazil are highest between the ages of 20–29 years and are four times higher for males than females.[6] In São Paulo, Brazil, motor-vehicle injuries were the largest cause of potential years of life lost among the economically active male population during 1980–1982.[7] Among all deaths certified as work-related in Brazil in the period 1979–1991, 33% were caused by motor-vehicle injury.[8]

Although an important fraction of all occupational injury fatalities are associated with motor-vehicle injuries, a possible role of occupational history on the risk of death from motor-vehicle injury does not appear to have been investigated. Risk factors examined in most studies have included driver's speed, consumption of alcohol and other psychotropic drugs, use of seat belts or helmets, and vehicle safety.[9–11]

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In a cohort study of deaths occurring among Brazilian steelworkers, we found that motor-vehicle injuries were the most frequent cause of death during employment, accounting for 36% of all deaths and 76% of all unintentional injury deaths.[12] Compared to age- and calendar year-specific mortality rates for the population of Minas Gerais, the State where the steelworks is located, there was a twofold excess risk of death from motor-vehicle injury in the cohort (standardized mortality ratio [SMR] = 209, 95% CI : 176–244). In order to explore this excess further, a nested-case control study was undertaken. The objective was to investigate the roles of socio-demographic and medical history factors and of working in stressful and hazardous conditions on the risk of death from motor-vehicle injuries.

TABLE 1 *Main risk factors investigated and sources of information*

	Risk factor	Source of information
Socio-demographic:	Marital status	
	Educational level	Personnel records
	Salary group	
Occupational:	Job category	
	Work area	Personnel records and
	Shift work	Industrial Hygienists
	Work hazards	
Medical history:	Neural or psychiatric disorder	
	Psychoactive drugs	Medical records
	Physical disabilities	
	Drinking habit	
Accident history:	Occupational injury	Medical records
	Other non-fatal injuries	

MATERIALS AND METHODS

The cohort comprised all male workers ever employed between 1 January 1977 and 31 August 1990 at the USIMINAS plant, in Minas Gerais, southeast Brazil. They were followed up to 30 November 1992 or their date of last employment, whichever was earlier. Further details have been given elsewhere.[12] The cases in the present study were all workers who had died of motor-vehicle injury while employed at the plant between 1 January 1977 and 30 November 1992. Underlying causes of death were ascertained from death certificates and coded according to the 9th revision of the International Classification of Diseases.

For each case, four controls were selected at random from all cohort members employed at the plant at the time of the case's death and born in the same year as the case.

Information on various factors (Table 1) for each case and his matched controls was extracted for the period of employment before the death of the case. For controls, an 'index date' was assigned corresponding to the month and year of death of the matching case. Socio-demographic data and marital status were abstracted from personnel records available on individual microfiches. For cases and controls, the marital status and salary grade recorded at the nearest date before the index date were abstracted for analysis. Number of years of school attendance had been recorded at commencement of employment. The personnel department provided complete documentation on the variation and equivalence between salary grades over time. It also provided information on the worker's shift pattern at the index date.

The occupational history also attempted to identify the workplace hazards at the time of death of the cases and the index date for the matched controls. Experienced industrial hygienists in the steel plant used information on workplace, job title and category to identify these work hazards. They were unaware of the study hypothesis and of the subject's case/control status. Intensities of exposure to noise, heat and vibration were classified as low, moderate or high, based on the levels of exposure and the threshold values adopted by Brazilian law on safety at work. The intensity for 'medium' noise exposure was 90–94 dB (A), and for 'high noise' was $\geqslant$95 dB (A).

The health histories of the cohort members were obtained from microfiches containing records on routine medical examinations by the Occupational Health Department. Steelworkers in the plant are examined at commencement of employment and then on a regular basis, generally every 2 years. Records were checked up to the index date for history of neurological and psychiatric disorders such as epilepsy, major depression, and persistent insomnia, and for use of psychoactive drugs. These records also provided information on the presence of physical disabilities, especially hearing and visual impairments, and current alcohol consumption. Medical records also provided information on injury history, inside and outside the workplace, from the date of starting work at USIMINAS to the index date. Injuries were classified according to whether they had been work-related.

Statistical Analysis

Since controls were individually matched to cases, the matching was preserved during analysis. Conditional logistic regression was used for both univariate and multivariate analyses, which were conducted using the Egret computer package.[13]

In the initial analysis, the association of each risk factor with death from motor-vehicle injury was examined. Interaction terms were added to test for heterogeneity of the odds ratios (OR), and statistical significance assessed by the likelihood ratio test.[13] Interaction with age, the matching factor, was explored by comparing the effect of the risk factor in two age groups: <30 years and ⩾30 years. Interaction with calendar period of death was investigated by examining risks: before 1985, and in 1985 onwards. For categorical and ordered variables a test for trend in the OR with increasing level of exposure was conducted.

Finally, the joint effects of the risk factors that appeared to be associated with death from motor-vehicle injuries were included in the same model. The statistical significance of the effect of including an explanatory variable in the model was obtained by comparing the difference in deviance between the models with and without the factor.[14]

RESULTS

There were 145 deaths from motor-vehicle injury among steelworkers during the study period: 25 (17%) in motorcyclists, 22 (15%) in pedestrians, and the remainder in occupants of cars or lorries. Seventy-three (50%) of these deaths were of workers below 35 years of age. In all, 580 matched controls were selected, but personnel records were incomplete for 27 of these, leaving 553 (95%) controls in the analysis.

The risk of death from motor-vehicle injury for workers with ⩾9 years of education was significantly reduced when compared to that of workers with <5 years of schooling (Table 2). Salary, however, was not statistically associated with risk. There was a highly significant increase in risk for single workers compared to married workers. Only a few cases and controls were divorced or widowed. Of married workers, 14% were recorded as heavy drinkers compared to 18% of single workers (not shown in Table), although drinking information was missing for many workers (see below).

There was a small non-significant increase in the risk of death from motor-vehicle injury for workers with a history of neuro-psychiatric disorders and/or use of a psychoactive drug (Table 2). Significant raised risks were found for workers with hearing deficiencies and for those with other physical disabilities. Risks were reduced for workers with a history of occupational injury and elevated for those with a history of non-occupational injury, but neither was statistically significant (Table 2).

The medical records lacked information on alcohol consumption for 22% of the cases and 16% of the controls. Missing records were more frequent in the early years of the study period, especially during the first two consultations with the occupational doctor. Before 1987, medical examination forms were not structured, and doctors tended to write down only ‘positive’ information, such as alcoholism. On the other hand, newly employed workers might more easily conceal their drinking habits. To reduce the bias that might result from missing data, the initial analysis was restricted to workers with ⩾4 years of employment. Workers with a record of alcohol abuse had a threefold increased risk of death from motor-vehicle injuries, although this was not statistically significant (Table 2). In general, adjusting the OR in Table 2 for education level made little difference to the results obtained.

There was no significant association of risk of death from motor-vehicle injury with job category, shift pattern, or area of work in the steel plant (Table 3). Risk increased significantly with increasing occupational noise exposure, but no significant associations were found with respect to exposure levels to heat, dust, or gas or vapour. Again, adjusting for educational level made little difference to the results obtained (Table 3).

In the multivariate analysis, the risk factors that were significantly associated with death from motor-vehicle injury in the univariate analysis (education, marital status, hearing and other physical disabilities, and occupational noise exposure) and those for which there was a suggestion of an association, although not significant (neuro-psychiatric disorders, history of occupational and non-occupational injuries, and exposure to heat and gases/vapours at work) were entered in the same model for mutual adjustment. Information on current drinking status was not included in the final model because of the large number of missing values. The significance of the inclusion of a factor in the model was tested by comparing the model with and without that particular factor. There was no evidence of an independent effect of education ($P = 0.15$), history of neuro-psychiatric disorder ($P = 0.42$), occupational and non-occupational injury ($P = 0.28$ and $P = 0.29$ respectively), or exposure to heat or gases/vapours ($P = 0.57$ and $P = 0.81$ respectively). The association for ‘other’ (non-aural) physical disabilities diminished slightly, and ceased to be statistically significant. These factors were not retained, therefore, in the final model.

Table 4 shows OR after mutual adjustment for the risk factors that remained significantly associated with motor-vehicle deaths in the multivariate analysis. In comparison with the univariate analysis, there was little

TABLE 2 *Risk of death from motor-vehicle injury according to socio-demographic factors and medical history*

Risk factor	No. of cases	No. of controls	OR (95% CI)	Adjusted OR (95% CI)
Education				
⩽4 years	47	153	1.00	1.00[a]
5–8 years	70	244	0.93 (0.54–1.45)	0.92 (0.59–1.46)
⩾9 years	28	156	0.58 (0.34–0.97)	0.58 (0.30–1.09)
			χ^2_1 trend = 4.1, P = 0.04	χ^2_1 trend = 2.5, P = 0.11
Salary group[c]				
low	8	27	1.00	1.00[b]
lower-middle	64	245	0.88 (0.46–1.67)	0.60 (0.29–1.23)
middle	53	194	1.12 (0.59–2.09)	0.66 (0.31–1.41)
upper-middle	17	60	1.12 (0.58–2.15)	0.58 (0.25–1.33)
high	3	22	0.83 (0.40–1.72)	0.44 (0.18–1.06)
			χ^2_1 trend = 0.2, P = 0.68	χ^2_1 trend = 0.9, P = 0.34
Marital status[d]				
married	89	420	1.00	1.00[b]
single	54	128	2.93 (1.72–4.99)	3.19 (1.85–5.51)
divorced or widowed	2	4	2.02 (0.37–11.12)	2.04 (0.36–11.69)
Neuro-psychiatric disorder or psychotropic drug use				
no	127	506	1.00	1.00[b]
yes	18	47	1.51 (0.85–2.67)	1.48 (0.83–2.64)
Hearing deficit				
no	132	531	1.00	1.00[b]
yes	13	22	2.47 (1.21–5.03)	2.36 (1.15–2.85)
Other physical disability				
no	135	536	1.00	1.00[b]
yes	10	17	2.29 (1.05–5.01)	2.41 (1.09–5.33)
History of occupational injury				
no	141	529	1.00	1.00[b]
yes	4	24	0.60 (0.21–1.77)	0.55 (0.19–1.61)
History of other injury				
no	135	529	1.00	1.00[b]
yes	10	24	1.62 (0.73–3.58)	1.66 (0.75–3.67)
Drinking habit[e]				
none	34	152	1.00	1.00[b]
moderate	55	199	1.35 (0.80–2.27)	1.40 (0.82–2.39)
heavy	4	7	3.07 (0.82–11.48)	3.34 (0.88–12.65)
			χ^2_1 trend = 2.7, P = 0.10	χ^2_1 trend = 3.1, P = 0.08

[a] Odds ratios adjusted for salary group.
[b] Odds ratios adjusted for level of education.
[c] Information missing for five controls.
[d] Information missing for one control.
[e] Odds ratios based on cases and controls with >4 years of employment: information missing for 15 cases and 47 controls.

change in the OR for single marital status and hearing deficit, which remained significant (Table 4). The trend in risk with increasing exposure to noise was greater and more highly significant than in the initial analyses. A separate analysis of workers with ⩾4 years of employment examined a possible confounding effect of drinking habit on the factors retained in the final model. There was no evidence of a significant change in the size of the OR shown in Table 4.

DISCUSSION

In this study the risk of death from motor-vehicle injury among steelworkers was significantly increased for unmarried workers, for those with hearing disability, and those exposed to moderate and high levels of noise at work. Since information was obtained from records made before the death of the case and at a corresponding time for his matched controls, there was no opportunity for recall bias in assessment of risk factors. Although

TABLE 3 *Risk of death from motor-vehicle injury among steelworkers in relation to job category, work schedule, work area and exposure to selected occupational hazards*

Occupational risk factors	No. of cases	No. of controls	OR (95% CI)	Adjusted OR[a] (95% CI)
Job category				
labourer	96	324	1.00	1.00
group leader[b]	10	43	0.80 (0.38–1.69)	0.87 (0.41–1.85)
clerical worker	18	88	0.68 (0.39–1.21)	1.11 (0.52–2.38)
technician	14	61	0.80 (0.43–1.49)	1.01 (0.52–1.99)
professional	7	32	0.74 (0.31–1.75)	1.43 (0.46–3.40)
Work schedule				
1 shift	29	137	1.00	1.00
2 shifts	32	124	1.22 (0.69–2.16)	0.97 (0.52–1.81)
3 shifts	84	292	1.35 (0.84–2.16)	1.06 (0.62–1.81)
			χ^2_1 trend = 1.6, $P = 0.21$	χ^2_1 trend = 0.1, $P = 0.76$
Work area				
management	10	52	1.00	1.00
production	61	218	1.02 (0.66–1.58)	0.78 (0.48–1.27)
support	74	283	1.27 (0.76–2.12)	1.03 (0.69–1.76)
Noise[c]				
none	41	198	1.00	1.00
low	27	126	1.03 (0.59–1.80)	0.89 (0.51–1.57)
moderate	42	140	1.44 (0.82–2.26)	1.20 (0.71–2.03)
high	35	88	1.75 (1.03–2.91)	1.55 (0.90–2.67)
			χ^2_1 trend = 5.7, $P = 0.017$	χ^2_1 trend = 4.8, $P = 0.029$
Heat[c]				
none	122	446	1.00	1.00
low	4	20	0.69 (0.23–2.07)	0.64 (0.20–1.94)
moderate	12	52	0.83 (0.42–1.62)	0.71 (0.36–1.42)
high	7	34	0.71 (0.31–1.65)	0.60 (0.26–1.40)
			χ^2_1 trend = 1.0, $P = 0.32$	χ^2_1 trend = 2.4, $P = 0.12$
Dust				
no	118	455	1.00	1.00
yes	27	98	1.05 (0.65–1.69)	0.94 (0.58–1.53)
Gases/vapours				
no	127	455	1.00	1.00
yes	18	98	0.86 (0.50–1.48)	0.74 (0.42–1.30)

[a] Odds ratios adjusted for level of education.
[b] Skilled manual worker who supervises the work of a group of labourers in the production line.
[c] Information missing for one control.

the records of some workers might have been misclassified with regard to exposure status, this misclassification could not have been influenced by case/control status. The coding of hazards by the industrial hygienists should not have been biased between cases and controls since the hygienists were blind to case/control status. Selection bias is unlikely because controls were randomly selected from members of the cohort employed at the time of death of the case.

The proportion of motor-vehicle deaths involving pedestrians was lower among steelworkers (15%) than that found in young men in the general population in Brazil,[5,15] but similar to that found in the US and Australia.[10,16] However, steelworkers may include a greater proportion of car owners than in the general population of Brazil. The proportion of motor-vehicle deaths involving motorcyclists (17%) was similar to that observed in the general population in Brazil.[15]

The study showed a large raised risk of motor-vehicle accident for single men. It is possible that if information on marital status in the company's records was not fully up-to-date, some men might have been misclassified with respect to marital status. There is no reason to believe, however, that misclassification was more likely for cases than for controls, because information came from the same source and records were checked up to the index date for cases and controls.

TABLE 4 *Multivariate analysis of risk factors for death from motor-vehicle injury*

Risk factor	No. of cases	No. of controls[a]	OR[b] (95% CI)	Adjusted OR[c] (95% CI)
Marital status				
married	89	419	1.00	1.00
single	54	128	2.93 (1.72–4.99)	3.21 (1.84–5.59)
divorced or widowed	2	4	2.02 (0.37–11.12)	1.95 (0.32–12.07)
Hearing defect				
no	132	529	1.00	1.00
yes	13	22	2.47 (1.21–5.03)	2.28 (1.10–4.74)
Exposure to occupational noise				
none	41	197	1.00	1.00
low	27	126	1.03 (0.59–1.80)	1.17 (0.66–2.06)
moderate	42	140	1.44 (0.82–2.26)	1.71 (1.03–2.83)
high	35	88	1.75 (1.03–2.91)	2.00 (1.18–3.39)
			χ^2_1 trend = 5.7, P = 0.017	χ^2_1 trend = 8.3, P = 0.004

[a] Information missing for two controls.
[b] Odds ratio.
[c] Odds ratios adjusted for all the other factors in the Table.

Non-differential misclassification would tend to be conservative, biasing results towards unity.[13]

Although many studies of risk factors for death from unintentional injury have shown elevated risk for unmarried men, there appear to have been no previous investigations for motor-vehicle fatality specifically. The explanations for the association may be similar, however, to those put forward for the general increase in risk of fatal injury in unmarried men. Married men have consistently been found to be mentally and physically healthier and have lower rates of mortality than unmarried men.[17–19] Marital status may influence lifestyle, as single and divorced men may, for instance, drink more than married ones,[17] and there was some evidence of this in our data. There could also be selection into marriage of less accident-prone men. The finding that single marital status seems to be an important predictor of death from motor-vehicle injury may be useful in defining target groups to approach in educational programmes.

The risk of death from motor-vehicle injury was raised, but not significantly so, for heavy drinkers, an established high risk group in the literature.[11,20] As is usual in studies involving histories of alcohol use, there is likely to have been misclassification of drinking status in this study, for instance because heavy drinkers may understate their habit, but differential misclassification of drinking status is unlikely. A non-differential misclassification of exposure would tend to bias the effect of excessive drinking towards the null, and hence the real OR may be greater than those estimated.[13] To minimize such misclassification we restricted the analyses to workers with >4 years of employment, because after two or more consultations doctors would have known workers better and have had access to data on absenteeism, which is common in alcoholics. Data on alcohol consumption in this group were missing for 15 cases and 47 controls, and it is possible that their exclusion might have produced some bias.

Of the occupational exposures examined, only noise was significantly associated with the risk of vehicular fatality. There was a highly significant increasing trend in risk of fatal motor-vehicle injury with increased intensity of exposure to noise, with significantly elevated OR for those exposed to moderate and high levels of noise. Protective devices were available and their use was nominally compulsory in noisy areas of USIMINAS, but it was noticed during data collection that many workers did not use these devices, mainly because of the discomfort they cause.

Although there appear to be no previous reports of raised risk of motor-vehicle mortality in relation to exposure to industrial noise, there are grounds for believing that such an association might be aetiological. Occupationally acquired hearing deficiency or short-term effects on concentration and alertness are potential pathways of causation of motor-vehicle accidents. Exposure to noise can damage the auditory system,[21–24] and an association with hearing damage might be underestimated by the study since we had data only on exposure at the time of death, not past exposures. Furthermore, duration of exposure might have been associated with hearing damage, and although total duration of employment was not associated with motor-vehicle death in the initial analysis, we had no data on duration of exposure to noise. Thus the statistically independent association with impaired hearing might, at least in part, be an occupational noise effect that was inadequately measured by the simple variable of current noise exposure. Also, any late effect of exposure to industrial noise would have been detected only incompletely in this study, since an important proportion of those affected would have left employment.

With regard to short-term effects of occupational noise exposure, individuals who are constantly exposed to noise might not be attentive to hazardous sounds when driving or crossing roads,[24] and there are reports of psychological reactions to noise such as nervousness and insomnia.[23–25] Those working in noisy areas might also be less attentive to velocity, since perception of speed seems more related to sound than vision.[20] The relation of noise exposure at work to motor-vehicle accidents deserves further study taking into account the intensity of exposure to noise, as well as other factors which were not available in our study, such as the duration of exposure, compliance with protective measures, and noise-annoyance. An association with motor-vehicle accidents could be of widespread importance since high levels of noise exposure are common in other occupations, as well as steelworkers. For instance, noise induced hearing loss and other ear diseases were the second most frequent category of claims for compensation in the Prescribed Diseases Statistics in Britain in 1990–1991.[21]

Physical disability other than hearing impairment (a wide range of disabilities) was also a significant risk factor for motor-vehicle fatalities in the univariate analyses, although not quite significant after adjustment for the other factors. Unfortunately there was no information available on the seriousness of physical impairments.

In the initial analysis, workers with more years of schooling had a significantly reduced risk of death. Other studies have reported an association between motor-vehicle mortality and low educational level.[25] One study in working populations found that educational attainment was directly associated with seat-belt use, speeding and drink-driving.[26] However in our study the association between motor-vehicle death and education did not remain statistically significant in the multivariate analysis. Information on level of education was obtained at employment and thus did not include the extent of training, especially in safety behaviours, during employment, which might be associated with reduced injury risk.

In conclusion, the significant associations found in this study between motor-vehicle fatality and single marital status, impaired hearing, and occupational noise exposure appear not to have been investigated previously. Bias is unlikely to explain them because the records of exposure were made before the death of the case. A confounding effect of alcohol intake cannot be ruled out, although there was no evidence for this in analyses of the subset of workers for whom data on regular drinking were available. Further investigation is needed to establish the associations found in this study and their implications for prevention of death from motor-vehicle injury.

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