Article

Accident Risk among People Employed in Poland—A Retrospective Cohort Study

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Abstract: The article presents studies aimed at determining the relative risk of accidents at work in all age groups of employees and the trend of possible changes in risk as a function of time in the years 2008–2018. The studies were conducted on the basis of statistics of accidents at work in Poland in the years 2008–2018. The data were collected from statistical yearbooks published by the Polish Central Statistical Office. The database covered 732,460 accidents at work. A retrospective cohort analysis of the relative risks for each year and the entire population was carried out. Through sensitivity testing, changes in the summary effect resulting from the removal of a given study were determined. The group with the highest average relative risk of accidents at work (2.59) were employees aged 18–19 years. An increase in relative risk was observed among employees aged +60 years. The smallest relative risk (0.33) was determined among employees under 18 years of age, who in Poland are mainly trainees and students.

Keywords: accident rate; cohort analysis; occupational risk

1. Introduction

Demographic change and the extension of the retirement age mean that the relative proportion of older employees is increasing and fewer young employees are entering the labor market. Accidents among young employees are often linked to a lack of experience and training [1–3], but it is important to remember that older employees are those with a lot of work experience but weaker motor skills than younger workers. When analysing employees’ behaviour at work, especially when the work is carried out in the presence of hazards, managers should assign tasks to employees which, e.g., due to their age or experience, they are able to cope with [4]. In order to be able to manage employees properly, managers need to know the groups of employees at risk.

Available in the literature, presented below results indicate multidirectional studies carried out all over the world for many years, taking into account both occupational and non-occupational factors that increase the risk of accidents. Non-occupational studies on the analysis of the relationship between workload and the risky behaviour of motorcyclists have been carried out [5]. It has been found that overwork is associated with the adoption of risky behaviour, and this fact can have an impact on the occurrence and severity of accidents. Work, gender, young age, smoking habits, alcohol abuse, overweight, psychotropic drug use, and illnesses were found to have an impact on accidents at work [6]. Other types of risk analysis of the impact of non-occupational factors include studies conducted by, e.g., [7], where deaths related to heat and cold were found to be 0.54% (5% CI—Clopper-Pearson confidence interval: 0.49–0.58) and 6.05% (95% CI: 5.59–6.36) of all deaths, respectively, including those at work.

Demographic changes in the world indicate the need to extend the period of professional activity. This need concerns, inter alia, European countries with negative
population growth and extension of life expectancy [8]. Demography causes shortages in the labour market, which are supplemented by older workers over the age of 65. It is also contributed by the growing role of services and process automation [9]. Older workers, being aware of their social role and greater awareness of the need to ensure safety [10], can be mentors for young workers starting their careers [11].

Older workers, due to age-related cognitive decline [12], tend to be more susceptible to certain accidents than young workers. One of the main causes of accidents may be the fact that for the oldest employees the most demanding is keeping the individual production potential of younger employees [13]. Working conditions should be designed to suit the health and functional abilities of older workers, which may mitigate the increasing threats to their safety [4,14]. Andersen et al. [15] on the basis of a stratified analysis, concluded that a good general psychosocial work environment increased the probability of work beyond retirement age, both for physically active people and those working in a sitting position.

Being aware of demographic changes, organizations must undertake organizational measures aimed at ensuring the safety of older workers. In Japanese companies, it has been observed that despite the implementation of many policies to promote the employment of older workers, accidents at work have been observed with a higher probability of killing victims aged 60 or over [16]. Therefore, employers should be encouraged to hire older workers in low-risk workplaces [17,18]. Varia-nou-Mikellidou et al. [4] argues that, to be effective, security-oriented strategies should be developed and adopted early in the working life and apply until retirement. Turek et al. [19], based on practices concerning older workers, distinguishes four groups of organizations—those that try to activate and develop their employees (active), focusing solely on the means of exit (exit), implementing a combination of development, adaptation, and outgoing activities (all) and does not practice age management (none).

Data on accidents at work are often published in the form of generally accepted W indicators. Breslin et al. [20] studied, among other things, the impact of work factors on the likelihood of a work-related disability or illness. In order to statistically analyse and interpret the number of accidents, the so-called indicator of accident frequency W (1–5).

\[
W = \frac{\text{number of fatal accidents}}{\text{total number of accidents}} \cdot 1000
\]  

(1)

\[
W = \frac{\text{absence caused by accidents}}{\text{number of victims}} \cdot 1000
\]  

(2)

\[
W = \frac{\text{total cost of accidents}}{\text{number of accidents}} \cdot 1000
\]  

(3)

\[
W = \frac{\text{number of injured}}{\text{number of employees}} \cdot 1000
\]  

(4)

\[
W = \frac{\text{number of injured}}{\text{number of hours worked}} \cdot 100,000
\]  

(5)

Accident indicators are also used by statistical offices as part of the analysis of the state of occupational safety in the country. For example, in Poland, according to CSO data [21], in the first quarter of 2020, the highest accident rate, calculated according to Formula (4), was recorded in the following sectors: mining and quarrying (indicator 3.0); water supply, sewage, and waste management (2.5); healthcare and social welfare (1.75). In the same branches of the economy, the highest accident rates were recorded in 2019: 16, 14, and 10 [21]. In addition, there are a number of other indicators that analyse the available data on accidents, specific industry, size of companies, age of employees, length of service, hours worked, etc.

Data on accidents, their nature and consequences is also analysed in the European Union, e.g., by the European Statistical Office—Eurostat. In the European labour market analyses, an accident is considered to be a sudden incident at work which has caused physical or mental injury. Accidents resulting in an inability to work for more than three
calendar days shall be recorded, not counting the day of the accident at work, and the fatal accident shall be considered to be those accidents which resulted in the worker’s death within one year of the event. An accident at work is any event which is related to work and which occurs on the premises of the workplace and also outside it, such as accidents in public transport. The most frequently analysed EU indicator is the standardised rate of accidents at work. Standardisation shall be carried out by assigning two weights to each accident. These weights relate to the level of reporting and the industry in which the accident occurred, and only nine activities according to the European classification of activities are taken into account. In the European Union (EU), over 2 million non-fatal work accidents resulted in workers being absent from work for four days or more in 2017, while 2912 of work-related accidents were fatal. The standardised incidence rate has fallen over the past seven years in the EU (since the start of comparable time series), from 2.87 fatal accidents per 100,000 workers in 2010 to 2.25 in 2017. Among individual EU Member states, 16 out of 27 EU Member States recorded a standardised incidence rate that was above the EU-average. The highest incidence rates were recorded in Romania with 5.72 fatal accidents per 100,000 workers, followed by Bulgaria (4.30), Austria (4.11), Portugal (3.86), France (3.58), and Lithuania (3.47) [8].

The results presented in literature are based on statistical analysis where surveys prevail [22,23] and developed logistic models [22], possibly using descriptor matrices and cluster analysis [24]. The result of such analysis is most often the odds ratio (OR) [25,26], which is a control-case study, indicating the chances that the phenomenon under investigation will occur. From a practical point of view, a more readable result for retrospective analysis is a cohort study for which the relative risk (RR) is determined, indicating the structure of the phenomenon in the population. It has been found that there are no cohort studies in literature indicating persistence or changes in risk trends among employee groups. The results of cohort studies published in the article were carried out for victims of accidents at work in Poland. The aim of the study was to determine the relative risk of accidents at work in all age groups of employees involved in the work process and to identify trends in possible changes in risk as a function of time.

2. Study Material and Methods

The study material consisted of statistical data concerning the number of victims of accidents at work and the number of employees in Poland. The data are collected by the Central Statistical Office (CSO) in Poland and published in the Statistical Yearbook and the Labour Statistical Yearbook [21]. For the analysis, data from the years 2008–2018 was used, excluding the years 2012, 2015, and 2016 for which the information published by the CSO was incomplete. The data used for the analysis is summarised in Tables 1 and 2. The adopted age ranges of employees are in line with the Statistics Poland system.

| Year | under 18 | 18–19 | 20–29 | 30–39 | 40–49 | 50–54 | 55–59 | 60–64 | 65 and More |
|------|----------|-------|-------|-------|-------|-------|-------|-------|------------|
| 2008 | 87       | 58    | 3669  | 4399  | 4028  | 2031  | 1184  | 415   | 134        |
| 2009 | 80       | 54    | 3537  | 4368  | 4006  | 2007  | 1253  | 354   | 227        |
| 2010 | 70       | 47    | 3487  | 4479  | 3990  | 1951  | 1355  | 465   | 234        |
| 2011 | 68       | 45    | 3186  | 3984  | 3538  | 1710  | 1097  | 376   | 189        |
| 2013 | 51       | 34    | 3017  | 4446  | 3874  | 1761  | 1602  | 674   | 285        |
| 2014 | 50       | 34    | 2970  | 4582  | 3967  | 1770  | 1652  | 739   | 254        |
| 2017 | 47       | 31    | 2982  | 4629  | 4089  | 1769  | 1682  | 854   | 322        |
| 2018 | 41       | 27    | 2943  | 4607  | 4168  | 1787  | 1574  | 899   | 363        |
Table 2. Injured in accidents at work in Poland (own elaboration based on [21]).

| Year | under 18 | 18–19 | 20–29 | 30–39 | 40–49 | 50–54 | 55–59 | 60–64 | 65 and More |
|------|----------|-------|-------|-------|-------|-------|-------|-------|-------------|
| 2008 | 172      | 1038  | 28,678| 27,311| 25,337| 13,391| 6860  | 1321  | 294         |
| 2009 | 150      | 638   | 21,889| 23,105| 21,196| 11,673| 6742  | 1380  | 315         |
| 2010 | 124      | 623   | 22,887| 25,248| 22,294| 12,476| 8316  | 1857  | 382         |
| 2011 | 130      | 670   | 23,745| 25,920| 22,373| 12,470| 9145  | 2390  | 379         |
| 2013 | 90       | 428   | 19,036| 23,894| 20,437| 10,621| 10,257| 3009  | 495         |
| 2014 | 94       | 549   | 19,491| 23,959| 20,432| 10,081| 9889  | 3546  | 600         |
| 2017 | 104      | 473   | 18,467| 22,692| 20,918| 9692  | 9802  | 5049  | 1133        |
| 2018 | 80       | 521   | 17,719| 21,605| 19,954| 9212  | 9243  | 4911  | 1058        |

The data were meta-analysed by determining, due to the cohort nature of the research, for individual years and for the whole analysed period as the final effect of the relative risk (RR) related to the occurrence of an accident at work in the analysed age group in relation to the remaining age groups of employees. RR was determined by means of Equation (6)

\[
RR = \frac{Q_{11} + Q_{12}}{Q_{21} + Q_{22}}
\]

where:

\[Q_{ij}\] — quantities observed in the quota table.

A zero hypothesis was assumed that \(H_0: RR = 1\) and an alternative hypothesis that \(H_1: RR \neq 1\). Test statistics expressed by Formula (7) have been used to verify the hypothesis that the risk of the phenomenon under investigation is the same in the vulnerable group and in the non-risk group.

\[
Z = \frac{\ln(\text{RR})}{\text{SE}}
\]

where:

\[
\text{SE} = \frac{1}{\sqrt{Q_{11}}} - \frac{1}{Q_{11} + Q_{12}} + \frac{1}{Q_{21}} - \frac{1}{Q_{21} + Q_{22}}
\]

— standard error of the RR logarithm.

When determining the parameter \(p\), each time the specified value was \(\alpha = 0.05\). Since the data concerned the same population (the same country), a common effect is presented for the collected data, by determining the permanent effect that the real (population) effect will be the same in each of these studies. Consequently, all the factors that could distort the magnitude of this effect are the same.

The study summary effect may vary depending on which studies are included in the analysis and which studies are excluded. The sensitivity test shall identify changes to the summary effect resulting from the exclusion of a given study. The tests should be similar enough that the exclusion of one of them does not completely change the interpretation of the assessment. In accordance with Formulae (6) and (7), an RR has been established for the base minus individual years, specifying the percentage change in the confidence interval with regard to the scope of the analysis for all years.

The relative risk of accidents at work in the different age groups of employees, which defines the risk compared to other groups. A group with a higher risk is defined by a value greater than 1 and a fraction less than 1 for the lower risk group. The value of the share of the remaining ones assigned to a given study defines the percentage which is the total weight of the remaining studies after exclusion of a given study. However, a change of precision indicates how the precision of the summary effect (width of the confidence interval) will change when a given study is excluded from the analysis.
The results indicate statistical significance of differences between risks for all age groups of employees. This is evidenced by the value of parameter $p < \propto$ that allows rejecting the zero hypothesis (H0), assuming the difference in relative risks in favour of the alternative hypothesis (H1). In addition, it was found that in each case the confidence interval does not contain a one, which indicates 95% confidence in the results.

The analyses were conducted in MS Excel 2019 (Microsoft, Redmond, Washington, U. S.), and PQstat v 1.6.8.384 (PQStat Software, Poznań).

3. Study Results

The results obtained for particular age groups of employees are presented in Table 3 below. The relative risk of accidents for individual years and age groups is graphically presented in forest plots (Figures 1–9). These figures show both the relative risk in each analysed year (a) and the value of total risk after excluding individual years (b).

Table 3. Summary of the meta-analysis for all age groups (own elaboration).

| Age of Employees /years | Relative Risk /RR | SE (ln RR) | −95%CI | +95%CI | $p$ Value |
|-------------------------|-------------------|------------|--------|--------|-----------|
| under 18                | 0.332             | 0.033      | 0.311  | 0.354  | <0.000001 |
| 18–19                   | 2.595             | 0.014      | 2.523  | 2.668  | <0.000001 |
| 20–29                   | 1.191             | 0.003      | 1.184  | 1.197  | <0.000001 |
| 30–39                   | 0.925             | 0.003      | 0.920  | 0.930  | <0.000001 |
| 40–49                   | 0.915             | 0.003      | 0.910  | 0.920  | <0.000001 |
| 50–54                   | 1.047             | 0.004      | 1.039  | 1.054  | <0.000001 |
| 55–59                   | 1.088             | 0.004      | 1.080  | 1.096  | <0.000001 |
| 60–64                   | 0.885             | 0.007      | 0.874  | 0.897  | <0.000001 |
| 65 and more             | 0.430             | 0.015      | 0.418  | 0.443  | <0.000001 |

Figure 1. The relative risk of an accident at work among employees up to 18 years old employed in Poland (own elaboration).
Figure 2. The relative risk of an accident at work among workers aged 18–19 years employed in Poland (own elaboration).

Figure 3. The relative risk of an accident at work among workers aged 20–29 years employed in Poland (own elaboration).

Figure 4. The relative risk of an accident at work among workers aged 30–39 years employed in Poland (own elaboration).

Figure 5. The relative risk of an accident at work among workers aged 40–49 years employed in Poland (own elaboration).
Figure 6. The relative risk of an accident at work among workers aged 50–54 years employed in Poland (own elaboration).

Figure 7. The relative risk of an accident at work among workers aged 55–59 employed in Poland (own elaboration).

Figure 8. The relative risk of an accident at work among workers aged 60–64 years employed in Poland (own elaboration).

Figure 9. The relative risk of an accident at work among workers aged 65 and over employed in Poland (own elaboration).
The variance of the observed effects for employees in the 20–54 age groups was within the range of 0.01 to 0.02. In the group of employees aged 18–19, the variance was 0.033, while in the groups: 60–64—0.058; +65 years—0.144. This proves the variability of the obtained results in the group of young and older employees, and thus the variability of RR as a function of the analysed years. The heterogeneity of data in the analysed age groups were in the range of 95 to 99%. For each age group, the asymmetry was tested using the Edgger’s test [27], obtaining $p > \alpha$ (0.05) in each case, which proves the lack of data load in individual years.

4. Discussion of Results

The results indicate a significantly higher risk of accidents at work among workers aged 18–19 years. The relative risk for the summary effect along with the 95% confidence interval is above one: $RR [95\% CI] = 2.59 [2.52–2.56]$, so it can be concluded that the risk of an accident at work in this age group is about 2.5 times higher than in the case of an employee from another age group and about 8 times larger than employees up to 18 years.

Employees aged 18–19 in the Polish labour market are most often the youngest full-time employees in companies. They are mostly employees with low professional qualifications doing simple work. Due to their age, they are people on the threshold of adulthood, with an underdeveloped sense of professional hierarchy, convinced that they are right in their own decisions and therefore often act against generally accepted principles. Furthermore, this group of employees has little professional and life experience, both in positive and negative terms. All of this means that in doing their job they are not fully aware of the risks involved and do not have the conviction that it is effective or advisable to comply with occupational safety guidelines. Unfortunately, as the statistics show, this attitude leads much more often to the generation of dangerous situations, the consequences of which are accidents at work [28–30]. As Figure 2 shows, this trend continues in all the years analysed. This thesis is confirmed by the comparable share of the remaining results after excluding one of the years from the analysis, presented in Table 4. This share ranged from 79 to 91%, and the change in the precision of the result did not diminish in any case. For example, after excluding the 2011 data from the analysis, the precision of the obtained summary decreases, i.e., the confidence interval for the final result is then 10.7% wider. The conclusion of such an analysis is that special attention needs to be paid by the employer, the health and safety workers and, above all, the immediate supervisors, who must be responsible in the workplace for shaping correct employee attitudes among these people. In addition, the legislator should introduce additional requirements for this age group in relation to the organisation of their work, e.g., the need to work under direct supervision or only as a team [1, 31,32].

Table 4. Sensitivity of the relative risk of an accident at work after deleting data (own elaboration).

| Age of Injured/Years | Year | 2008 | 2009 | 2010 | 2011 | 2013 | 2014 | 2014 | 2018 |
|----------------------|------|------|------|------|------|------|------|------|------|
| Under 18             | Share of the remaining ones/% | 80.98 | 83.41 | 86.29 | 90.04 | 90.01 | 89.60 | 88.49 | 91.15 |
|                      | Change of precision/%        | 13.63 | 9.05  | 9.39  | 6.02  | 6.02  | 5.50  | 3.32  | 3.36  |
| 18–19                | Share of the remaining ones/% | 78.99 | 87.13 | 87.41 | 86.44 | 91.34 | 88.87 | 90.41 | 89.40 |
|                      | Change of precision/%        | 10.63 | 9.92  | 8.97  | 10.70 | 6.03  | 4.32  | 4.18  | 1.26  |
| 20–29                | Share of the remaining ones/% | 84.13 | 87.51 | 86.79 | 86.31 | 88.62 | 88.41 | 88.87 | 89.34 |
|                      | Change of precision/%        | 7.65  | 7.14  | 7.79  | 8.74  | 6.59  | 5.81  | 6.09  | 5.52  |
| 30–39                | Share of the remaining ones/% | 85.84 | 88.09 | 87.03 | 86.64 | 87.77 | 87.73 | 88.17 | 88.73 |
|                      | Change of precision/%        | 7.75  | 6.13  | 6.80  | 7.32  | 6.45  | 6.77  | 7.22  | 6.79  |
| 40–49                | Share of the remaining ones/% | 85.51 | 87.90 | 87.16 | 86.99 | 87.82 | 88.14 | 97.96 | 88.52 |
|                      | Change of precision/%        | 7.39  | 6.04  | 6.70  | 7.47  | 8.41  | 6.59  | 6.31  | 6.35  |
| 50–54                | Share of the remaining ones/% | 85.15 | 87.15 | 86.23 | 86.16 | 88.12 | 88.64 | 89.03 | 89.52 |
Employees with less experience than the 18–19 age group are employees under 18 years of age. For this group of workers the relative risk of accidents at work is $RR \ [95\% CI] = 0.33 \ [0.31-0.35]$. Polish legislation allows employers to employ persons once they reach the age of 16. Until they reach the age of majority (18 years), these employees are juvenile and being under special protection they can only be directed to so-called light work that should be defined beforehand by the employer. This group of employees cannot be employed for work included in the list of prohibited work. The employer is also bound by specific working time standards. The daily dimension of juvenile time cannot exceed 6 h. In addition, young workers must not be employed overtime or at night, and other limit values are set for risks such as a lower net energy expenditure burden. This means that people under the age of 18 usually perform simple office work or seasonal work that do not involve a high level of risk.

Large differences in the relative risk were observed among the oldest group of workers, aged 65 and over. For this group of employees $RR \ [95\% CI] = 0.43 \ [0.42-0.44]$. It can therefore be concluded that the risk is more than half that of other employees. All employees of this age group already have full pension benefits (women starting at 60 years of age, men at 65 years). Therefore, their work is often part-time or advisory (expert) work [33,34]. Usually, these employees do not perform production work and are not employed as blue-collar workers. Therefore, the accident risk associated with their work is significantly lower than in other age groups. Similarly, a lower than average risk was observed in the group of employees aged 60–64 — $RR \ [95\% CI] = 0.89 \ [0.87-0.90]$. This risk is higher than in the group of older employees, as men obtain pension rights after reaching 65 years of age. It is therefore often the case that men perform dangerous production work after the age of 60. In the study [35], it was found that with age, multitasking is declining in employees. In the case of these two groups of older employees, there is a worrying trend that risk levels will increase in 2017 and 2018, compared to previous years, as shown in figures 8 and 9. For employees aged 65 and over in 2017 $RR \ [95\% CI] = 0.65 \ [0.61-0.69]$, and for workers aged 60–64 in 2017 $RR \ [95\% CI] = 1.10 \ [1.01-1.13]$, which is above average. Such results can be explained by the shortage of the labour market, which is largely supplemented by foreign employees (in the years 2014–2020 an increase by 600 thousand—about 480%) [21,36] and retired employees [33,34]. Shortages of employees in the labour market resulted in an increase in the weekly working time of people aged over 65 in 2016 and 2017 by about 5 h per week compared to 2010 (28.3 h/week in 2010, 33.2 h/week in 2017). No such increase was recorded in the remaining age groups [33,34]. This confirms the conclusions of Bartkowiak et al. [37] that in 2019, compared to 2014, there was an increase in entrepreneurs’ awareness of the role of experienced (older) employees in their companies. These jobs, which are tailored to younger employees, may not be sufficiently secure for older employees with lower perception and motor skills [12,13,18,38]. It should be noted that each employee must be admitted to work by an occupational medicine physician. Gander et al. [39] concluded that demographic and social trends in industrialised countries would lead to an increase in the number of older shift workers, raising concerns about possible health and safety risks. The International Labour Organisation recommended the possibility of moving to day work or early retirement especially in the case of older night workers. Varianou-Mikellidou et al. [4] identify what changes are taking place in ageing workers as a result of physical and
5. Conclusions

Accident statistics annually show that the numbers of people injured in accidents at work vary across age groups. This is due to the level of employees' awareness and the changes in the human body’s motor skills during life. From a practical point of view, a more readable result for retrospective analysis of the accident rate is a cohort study for which the relative risk (RR) is determined, indicating the structure of the phenomenon in the population.

Based on the analysis of 732,460 accidents at work in Poland in 2008–2018, it was found that participation in an accident at work;

- workers aged 18–19 are the most vulnerable group,
- workers aged up to 18 are the least exposed group.

In each of the analysed years, the accident risk higher than the average was observed among employees aged 20–29, and lower than the average among employees aged 30–49.

Between 2017 and 2018 an increase in accident risk was observed among workers aged +60. It must be assumed that this trend will continue, as demographic change is forcing older workers to be more often employed. Therefore, their positions and work they are commissioned to do should be adapted to the psychophysical abilities of older people.

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