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Exploratory Analysis of Spanish Energetic Mining Accidents

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Using data on work accidents and annual mining statistics, the paper studies work-related accidents in the Spanish energetic mining sector in 1999–2008. The following 3 parameters are considered: age, experience and size of the mine (in number of workers) where the accident took place. The main objective of this paper is to show the relationship between different accident indicators: risk index (as an expression of the incidence), average duration index for the age and size of the mine variables (as a measure of the seriousness of an accident), and the gravity index for the various sizes of mines (which measures the seriousness of an accident, too). The conclusions of this study could be useful to develop suitable prevention policies that would contribute towards a decrease in work-related accidents in the Spanish energetic mining industry.

energetic mining   risk index   average duration index   gravity index   mining accidents

1. INTRODUCTION

In the total number of Spanish economic sectors, mining is one of those with a high index of annual incidences, i.e., the number of accidents per 100 000 workers. In 2006, Spanish mining had an incidence index 4.7 times higher than all economic sectors [1, 2, 3]. If the indices of work accidents in Spanish mining are compared with those of other countries, we can see that their values are also much higher. Specifically, in 2006, the index of annual incidence was 8.9 times higher than in the USA [4] and 20.4 times higher than in the State of Queensland (Australia) [5]. The Spanish mining sector can be classified into two types, energetic and nonenergetic mining. Energetic mining includes activities related to extraction and agglomeration of coal, extraction of uranium and thorium, and extraction and preparation of any solid fuel. Petrol and gas extraction are not included. Nonenergetic mining includes the extraction and preparation of metallic and nonmetallic minerals and quarry products such as limestone, marble, granite, sand and gravel or clay, with the

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purpose of producing aggregates, cement, ornamental stones, concrete or ceramic products. The indices of annual incidences in energetic mining [1] are significantly larger than in nonenergetic mining [2]. In 2006, this index was 2.7 times higher than in the nonenergetic sector.

Most accidents are caused by human error [6], and many of those are experienced by relatively few workers [7]. The first event that immediately precedes an accident is mostly caused by environment factors, while the second event, i.e., the event that takes place immediately before the first one, is mainly attributed to behaviour factors [8].

This paper considers several characteristics. Specifically, it analyses the relationship between work-related accidents and the age of workers, occupational experience and the size of the mining work centre (defined by the number of employees).

Many researchers studied the effect of age and mining experience on the occurrence of accidents; different conclusions followed. The National Research Council found a strong negative link between age and the seriousness of the lesions of injured workers in coal mines [9]. Younger injured workers seemed more seriously injured than the older ones. Bennett did not find any relationship between age and the seriousness of the injury; the author concluded that less experienced miners were slightly more likely to have an accident than more experienced ones [10]. However, Bennett and Passmore showed that older injured miners were more likely to have serious or fatal injuries than younger ones [11].

Butani noted that injuries in the coal industry were more related to experience than to age, and less experience increased the probability of an accident [12]. Specifically, this study concludes that there exists a significant occupational experience effect with the largest increase in risk occurring in workers over 50 years old with under one year of occupational experience. In their study on transport injuries in small coal mines, Hunting and Weeks reported an increased risk of injury with less experience but no age effect [13]. They also observed that small coal mines had the highest rates of transport-related injuries. Moreover, small mines had a greater share of fatal and permanently disabling injuries, whereas the large mines had a greater share of injuries involving no lost workdays. On the other hand, some studies showed how accidents in the workplace could be attributed to personal and environmental factors [14, 15, 16, 17].

Groves, Kecojevic and Komljenovic classified accidents taking into account the machine or equipment used when the accident happened [18]. A similar study has been impossible with our available mining data. In this paper, information on the machine or equipment has been substituted with seven frequent types of accidents occurring in underground and surface mining.

We can note that a wide variety of results has been offered in the literature depending on the available mining data. In this article, we have presented and analysed data on accidents in the Spanish energetic mining sector in 1999–2008. The conclusions may be used in planning appropriate safety programs and measures such as engineering, enforcement, education or technological advances, to warn against injuries or fatal accidents in the energetic mining sector in the future.

2. METHODS

2.1. Study Population

The study population comprised accidents that took place in the Spanish energetic mining sector in 1999–2008, within the work schedule (we did not consider accidents which happened on one's way to or from work) which caused the injured worker to lose at least one workday.

The data were obtained from the annual digital database of the Ministry of Employment and Social Security with ArcGis 9.2[1]. It is important that the annual accident database does not supply separate information about underground mining activities and surface ones for 1999–2002. However, this information is available for 2003–2008, and the two kinds of mining activities can be distinguished. In this paper, we analyse the overall accidents which happened in the indicated period or only the accidents corresponding to 2003–2008, according to information from the database.

The percentage of workers in the Spanish energetic mining who were divided into seven age groups and into six types of work centres, were obtained from the yearbooks of work statistics of Spain's Ministry of Work and Immigration from 1999–2008 and the yearbooks of mining statistics of Spain's Ministry of Industry, Tourism and Commerce for 1999–2006.

2.2. Description of the Methodology

The study was divided into underground and surface mining, but this only applied to 2003–2008, since in 1999–2002 the location of the accidents was unknown (see section 2.1.).

We considered the workers' age and the size of the work centre (defined by the number of employees) where the accident took place. There were seven age groups (16–24, 25–29, 30–34, 35–39, 40–44, 45–54 and ≥55 years), six sizes of work centres (1–9, 10–19, 20–49, 50–99, 100–499 and ≥500 workers) and six experience groups (0–12, 13–60, 61–120, 121–180, 181–240 and ≥241 months) for seven kinds of accidents.

A risk index is defined as the ratio of the percentage of injuries attributed to a given subpopulation (age group or size of work centre) to the percentage of the total workforce represented by that subpopulation [12]. A risk index of 1 corresponds to an average risk, while a value greater than 1 indicates a higher risk for that group. Thus, to calculate the risk index, we needed to know the percentage of accidents that happened in each age groups or work centre, and the percentage of workers in them. We also calculated the average duration index (ADI) for each age group (1999–2007) and for each size of the work centre (1999–2006); it indicated the seriousness of accidents.

Once the risk index and the ADI for the age groups were calculated, we analysed the relationship between the risk index (as an indicator of the incidence of accidents in a population) and the ADI (as an indicator of the severity of the accidents), and both the age and the size of the work centres. This was done with the nonparametric statistical Spearman rank correlation. The mean was calculated for the total population in 1999–2006 or 1999–2008. Throughout this paper, analyses were conducted at a .05 significance level.

The results were analysed in two ways. The Mann–Whitney *U* test was used to observe if there was a significant difference between underground and surface mining in the distribution of the ADI, depending on the occupational experience of the injured parties. Spearman rank correlation coefficient was used to analyse the relationship between the ADI and the workers' experience in the seven types of the most frequent accidents in underground and surface mining.

3. RESULTS AND DISCUSSION

3.1. Age and Experience of Injured Workers

Table 1 shows data on the percentage of workers in 1999–2008 per year, per age group, for the seven age groups. The results in Table 2 show a significantly greater risk in the 16–24, 25–29, 30–34 and 35–39 age groups, with the highest estimated risk indices. At the same time, the risk index was significantly lower for the 45–54 and, especially, ≥55 groups.

Spearman rank correlation coefficients, calculated for each year, show that the incidence of accidents (expressed with the risk index) is correlated with the workers' age: all coefficients are over the critical value of .714. The correlation is negative, i.e., when the workers' age increases, the incidence of accidents decreases (Table 2). Table 2 illustrates accidents for each age group, the risk index and Spearman rank correlation coefficient for each year between 1999 and 2008.

To analyse the possible relationship between the seriousness of the accidents and the age of the workers, the ADI for each age group was calculated with data from Table 3 (Table 4). Spearman rank correlation coefficients were higher than the critical value, except in 2005 and 2006. This indi-

[1] http://www.esri.com/software/arcgis/arcgisserver/

TABLE 1. Energetic Mining Population by Age Group (1999–2008)

	Age Group (%)						
Year	**16–24**	**25–29**	**30–34**	**35–39**	**40–44**	**45–54**	**≥55**
1999	3.09	7.73	19.07	31.96	26.29	9.79	2.06
2000	2.75	6.59	18.13	31.32	29.12	10.44	1.65
2001	2.41	6.02	16.87	30.72	30.72	10.84	2.41
2002	2.01	6.04	15.44	30.87	32.21	11.41	2.01
2003	2.24	5.97	14.18	30.60	32.84	12.69	1.49
2004	1.68	5.88	12.61	30.25	32.77	14.29	2.52
2005	1.92	5.77	11.54	29.81	32.69	15.38	2.88
2006	2.13	5.32	11.70	28.72	32.98	17.02	2.13
2007	2.33	5.81	11.63	26.74	32.56	18.60	2.33
2008	2.53	6.33	12.66	24.05	34.18	18.99	1.27
M	2.37	6.27	15.15	30.07	31.06	13.01	2.07

TABLE 2. Distribution of Accidents by Age Group and Estimated Risk Index (1999–2008)

	Age Group (%)							Risk Index							Spearman Correlation
Year	**16–24**	**25–29**	**30–34**	**35–39**	**40–44**	**45–54**	**≥55**	**16–24**	**25–29**	**30–34**	**35–39**	**40–44**	**45–54**	**≥55**	
1999	4.31	8.33	20.82	33.63	26.76	5.52	0.64	1.39	1.08	1.09	1.05	1.02	0.56	0.31	–.964
2000	4.41	8.04	20.59	31.67	29.09	5.54	0.66	1.60	1.22	1.14	1.01	1.00	0.53	0.40	–1.000
2001	2.58	6.74	19.03	34.04	32.15	4.87	0.59	1.07	1.12	1.13	1.11	1.05	0.45	0.25	–.750
2002	2.87	7.43	16.65	32.85	34.56	5.22	0.41	1.42	1.23	1.08	1.06	1.07	0.46	0.21	–.964
2003	2.79	7.99	14.70	33.22	35.01	5.84	0.44	1.25	1.34	1.04	1.09	1.07	0.46	0.30	–.857
2004	2.37	7.79	13.55	34.38	35.80	5.61	0.49	1.41	1.33	1.07	1.14	1.09	0.39	0.19	–.893
2005	2.49	7.55	13.73	34.55	35.12	5.87	0.70	1.29	1.31	1.19	1.16	1.07	0.38	0.24	–.964
2006	2.81	7.60	13.76	33.37	34.81	7.03	0.62	1.32	1.43	1.18	1.16	1.06	0.41	0.29	–.964
2007	3.43	7.25	15.89	30.83	34.67	7.30	0.62	1.48	1.25	1.37	1.15	1.07	0.39	0.27	–.964
2008	3.93	7.88	16.63	27.25	34.88	8.47	0.96	1.55	1.24	1.31	1.13	1.02	0.45	0.76	–.929
M	3.33	7.71	17.44	32.86	32.25	5.81	0.60	1.40	1.23	1.15	1.09	1.04	0.45	0.29	–1.000

cates a positive correlation between the workers' age and the seriousness of the accident. This coincides with Bennet and Passmore's results [11].

Table 5 shows the ADIs for the seven most frequent types of accidents in underground and surface energetic mining, according to the experience of the injured workers.

We calculated the Spearman rank correlation coefficient for each type of accident to evaluate the relationship between experience and the ADI. The null hypothesis can be rejected only for accident 50 (contact with a cutting, piercing, hard or rough material agent), for underground energetic mining. In the other kinds of accidents in underground and surface mining, the null hypothesis cannot be rejected because the Spearman rank correlation coefficients are under the critical value of .786. So, for the other types of accidents, there is no statistically significant relationship between the injured parties and the seriousness of the accidents expressed through the ADI.

To compare the ADI for each group, considering experience in underground and surface energetic mining, we used the Mann–Whitney *U* test. The results showed the null hypothesis could not be rejected for accident 31 (blow, or hitting something as a result of a fall), 32 (blow as a result of a fall, or crashing into an immovable object), 71 (physical overexertion of the musculoskeletal system) and the remaining types of accidents (considered as one type). We concluded that there was no significant difference between

TABLE 3. Distribution of Lost Workdays and Nonfatal Accidents by Age Group (1999–2008)

	Lost Workdays							
Year	16–24	25–29	30–34	35–39	40–44	45–54	≥55	Total
1999	9635	18 237	48 436	85 356	72 940	16 206	2313	253 123
2000	9544	18 735	43 832	73 243	71 067	17 211	2078	235 710
2001	5033	14 252	47 890	89 861	90 407	15 850	1544	264 837
2002	5178	13 938	32 095	69 485	76 711	12 164	851	210 422
2003	4248	13 455	23 494	59 635	66 526	11 623	863	179 844
2004	2270	9149	16 241	46 469	50 023	8551	1087	133 790
2005	2779	8892	17 048	35 815	38 206	7878	1031	111 649
2006	2411	5832	11 563	27 040	32 702	6403	655	86 606
2007	1988	6247	15 304	30 394	30 467	8785	1025	94 210
2008	2557	5458	12 438	20 520	25 733	7828	1574	76 108
total	45 643	114 195	268 341	537 818	554 782	112 499	13 021	1 646 299

	Nonfatal Accidents							
Year	16–24	25–29	30–34	35–39	40–44	45–54	≥55	Total
1999	495	955	2391	3859	3075	634	74	11 483
2000	464	847	2162	3329	3060	581	70	10 513
2001	235	614	1735	3101	2929	444	54	9112
2002	215	557	1248	2462	2589	391	30	7492
2003	182	520	959	2164	2283	381	29	6518
2004	136	450	782	1983	2066	322	28	5767
2005	114	345	628	1582	1606	268	32	4575
2006	108	295	534	1295	1350	273	24	3879
2007	133	280	615	1194	1344	281	24	3871
2008	139	279	589	964	1234	298	34	3537
total	2221	5142	11 643	21 933	21 536	3873	399	66 747

TABLE 4. Distribution of Average Duration Index for Nonfatal Injuries by Age Group (1999–2008)

	Average Duration Index							Spearman
Year	16–24	25–29	30–34	35–39	40–44	45–54	≥55	Correlation
1999	19.46	19.10	20.26	22.12	23.72	25.56	31.26	.964
2000	20.57	22.12	20.27	22.00	23.22	29.62	29.69	.893
2001	21.42	23.21	27.60	28.98	30.87	35.70	28.59	.787
2002	24.08	25.02	25.72	28.22	29.63	31.11	28.37	.893
2003	23.34	25.88	24.50	27.56	29.14	30.51	29.76	.929
2004	16.69	20.33	20.77	23.43	24.21	26.56	38.82	1.000
2005	24.38	25.77	27.15	22.64	23.79	29.40	32.22	.464
2006	22.32	19.77	21.65	20.88	24.22	23.45	27.29	.714
2007	14.95	22.31	24.88	25.46	22.67	31.26	42.71	.893
2008	18.40	19.56	21.12	21.29	20.85	26.27	46.29	.893
total	20.55	22.21	23.05	24.52	25.76	29.05	32.63	1.000

TABLE 5. Average Duration Index for 7 Types of Accident-Related Injuries Depending on Experience in Underground and Surface Mining (2003–2008)

Experience in Underground Mining	Average Duration Index							
	71	42	50	32	40	41	31	All Types of Accidents
Nonfatal injuries	5084	4925	3874	1353	1317	882	840	23 970
Fatalities	0	4	0	0	0	1	3	20
Lost workdays (nonfatal injuries)	120 680	122 033	80 711	26 647	37 606	14 498	22 190	569 774
Type of accident (total)	23.74	24.78	20.83	20.23	27.79	16.44	26.42	23.77
0–12 months	23.81	25.43	21.69	23.20	24.67	16.77	23.84	24.56
13–30 months	25.95	23.82	28.30	14.60	37.75	19.95	24.17	26.17
31–60 months	23.45	21.78	20.27	63.60	7.24	18.95	29.81	22.42
61–120 months	22.64	25.97	18.79	14.88	41.42	15.98	26.41	23.29
121–180 months	25.97	22.39	18.63	45.92	16.27	14.61	25.26	24.01
181–240 months	22.34	23.46	16.86	14.79	25.79	10.97	26.67	21.50
≥241 months	27.26	32.64	15.09	16.29	17.06	18.20	51.25	27.80
Spearman correlation	.143	.179	–.964	–.071	–.143	–.464	.750	–.071

Experience in Surface Mining	Average Duration Index							
	71	42	31	32	44	41	63	All Types of Accidents
Nonfatal Injuries	424	211	116	73	57	49	43	1372
Fatalities	0	1	0	0	0	0	0	3
Lost workdays (nonfatal injuries)	10 266	6111	3264	1662	1286	660	1292	34 513
Type of accident (total)	24.21	28.96	28.14	22.77	22.56	13.47	30.05	25.16
0–12 months	21.49	24.59	27.57	20.69	31.26	13.72	24.29	23.94
13–30 months	20.69	37.93	28.05	19.00	20.50	7.33	22.50	23.18
31–60 months	30.03	28.73	26.95	17.33	14.54	28.75	38.63	27.61
61–120 months	21.46	32.38	38.63	49.50	16.20	4.40	28.00	23.47
121–180 months	22.64	24.71	14.83	18.20	28.00	12.25	27.00	24.94
181–240 months	27.44	40.47	32.37	22.25	23.50	13.25	46.83	28.98
≥ 241 months	26.65	26.95	21.83	32.33	14.50	14.00	0.00	26.06
Spearman correlation	.464	.214	–.214	.393	–.429	.107	.071	.393

Notes. 31—blow, or hitting something as a result of a fall; 32—blow as a result of a fall, or crashing into an immovable object; 40—crashing into or hitting a moving object; 41—being hit by an object or projected fragments; 42—being hit by a falling object or one that is detached; 44—crash or blow against a moving object, including vehicles (immovable worker); 50—contact with a cutting, piercing, hard or rough material agent; 71—physical overexertion of the musculoskeletal system; 63—being trapped or flattened.

energetic underground and surface mining for those four types of accidents. This is not the case for accident 41 (being hit by an object or projected fragments) or 42 (being hit by a falling object or one that is detached), since the null hypothesis is rejected because in both cases the *U* values are under or equal to the critical value.

3.2. Size of the Mines

Table 6 shows the percentage of workers by year and size of mine, for 1999–2006. The workforce is divided into six sizes of mines (in number of workers) classified in percentage per year.

Tables 6–7 show how the total number of accidents does not coincide exactly with the number of those in Table 2. This is so because in the classification according to size, the database field has missing values. Mining data for 2007–2008 were not published yet and, consequently, we could not calculate either the percentage of workers according to the size of the mines or the risk index for those years.

TABLE 6. Energetic Mining Population by Size of Mine (1999–2006)

	Size of Mine (%)					
Year	1–9	10–19	20–49	50–99	100–499	≥500
1999	0.24	0.79	3.77	4.31	21.64	69.25
2000	0.22	0.84	4.09	5.87	23.09	65.88
2001	0.20	1.20	3.94	4.73	21.25	68.68
2002	0.36	0.94	4.60	5.78	22.70	65.61
2003	0.32	1.18	3.89	6.20	22.32	66.10
2004	0.20	1.41	5.76	5.70	24.62	62.31
2005	0.31	1.78	3.35	6.83	33.63	54.09
2006	0.29	1.45	4.32	5.72	37.19	51.04
M	0.27	1.20	4.22	5.64	25.80	62.87

The results in Table 7 indicate a significantly greater risk for 1–9 workers (especially), 10–19, 20–49 and 50–99 workers, with the estimated risk indices of 3.33, 1.25, 1.26 and 1.32, respectively. At the same time, risk was significantly lower for the 100–499 category, with an index of .76. It should be noted that 100–499 workers (especially) and ≥500 workers were the safest categories in 1999–2006. The 1–9 workers category was more dangerous because the risk index was significantly higher than for the other groups. These results coincide with studies that established that the proportion of accidents was greater in small mines [13, 20].

Spearman coefficients calculated for distributions of the risk index according to the size of the mines showed that there was no correlation between accidents and the size of the mines. The null hypothesis can be rejected for 1999 and 2002 only. For other years, Spearman rank correlation coefficients were high (except for 2004), but they

TABLE 7. Distribution of Accidents by Size of Mine and Estimated Risk Index (1999–2006)

	Size of Mine (%)						Risk Index						
Year	1–9	10–19	20–49	50–99	100–499	≥500	1–9	10–19	20–49	50–99	100–499	≥500	Spearman Correlation
1999	1.33	1.69	4.58	4.46	18.01	69.93	5.47	2.13	1.21	1.04	0.83	1.01	–.943
2000	1.33	1.80	4.16	7.46	17.80	67.45	6.13	2.13	1.02	1.27	0.77	1.02	–.786
2001	0.54	1.20	3.73	6.40	19.88	68.26	2.70	1.00	0.95	1.35	0.94	0.99	–.600
2002	0.75	1.59	5.74	6.18	18.19	67.55	2.05	1.68	1.25	1.07	0.80	1.03	–.943
2003	1.07	1.29	4.68	8.61	19.53	64.81	3.40	1.10	1.20	1.39	0.88	0.98	–.714
2004	0.71	1.04	5.06	8.96	18.62	65.62	3.58	0.74	0.88	1.57	0.76	1.05	–.143
2005	0.72	1.53	5.98	9.95	20.34	61.48	2.29	0.86	1.78	1.46	0.60	1.14	–.543
2006	0.67	1.86	8.74	7.71	24.74	56.29	2.34	1.28	2.02	1.35	0.67	1.10	–.771
M	0.89	1.50	5.33	7.47	19.64	65.17	3.33	1.25	1.26	1.32	0.76	1.04	–.714

TABLE 8. Distribution of Accidents and Lost Workdays by Size of Mine Categories (1999–2008)

	Lost Workdays						Nonfatal Accidents					
Year	1–9	10–19	20–49	50–99	100–499	≥500	1–9	10–19	20–49	50–99	100–499	≥500
1999	3348	4755	12 308	10 048	46 903	141 777	140	177	481	468	1885	7336
2000	3251	4732	9824	15 472	43 806	131 631	129	175	403	722	1724	6547
2001	1510	3188	7823	13 173	47 536	179 492	47	105	326	559	1738	5970
2002	1215	2475	9583	11 269	37 498	141 554	54	115	416	448	1318	4894
2003	1757	1900	7992	12 574	34 458	118 790	69	82	301	553	1255	4160
2004	1541	1415	7923	12 592	29 353	80 966	41	60	291	516	1074	3785
2005	1341	2153	6543	11 981	23 769	65 862	33	70	273	453	930	2816
2006	505	2200	7905	6577	24 044	45 348	26	72	338	299	959	2184
2007	577	3557	10 343	8773	37 819	33 119	21	140	425	389	1344	1551
2008	745	2461	10 014	8526	29 533	24 829	41	80	386	421	1178	1431
total	15 790	28 836	90 258	110 985	354 719	963 368	601	1076	3640	4828	13 405	40 674

were lower than the critical value (.829). All the coefficients were negative.

To analyse the possible relationship between the seriousness of the accidents and the size of the mines, we calculated the ADI for each group. Spearman rank correlation coefficients were lower than the critical value, except in 2002 and 2005 (the two coefficients had different signs). This indicates that there is no correlation between the size of the mines (defined by the number of

TABLE 9. Distribution of Average Duration Index for Nonfatal Injuries by Size of Mine Categories (1999–2008)

	Average Duration Index						
Year	1–9	10–19	20–49	50–99	100–499	≥500	Spearman Correlation
1999	23.91	26.86	25.59	21.47	24.82	19.32	–.543
2000	25.20	27.04	24.32	21.34	25.32	20.08	–.543
2001	32.13	30.36	24.00	23.52	27.32	30.05	–.486
2002	22.50	21.52	23.04	25.15	28.45	28.92	.943
2003	25.46	22.89	26.55	22.74	27.46	28.53	.600
2004	37.59	23.58	27.13	24.36	27.31	21.37	–.486
2005	40.64	30.76	23.88	26.27	25.50	23.38	–.829
2006	19.42	30.56	23.32	22.00	25.05	20.76	.029
2007	27.48	25.41	24.34	22.55	28.14	21.35	–.429
2008	18.17	30.76	25.94	20.25	25.07	17.35	–.371
M	26.27	26.80	24.80	22.99	26.46	23.69	–.429

TABLE 10. Distribution of Accidents and Worked Hours by Size of Mine Category (1999–2006)

	Lost Workdays					
Year	1–9	10–19	20–49	50–99	100–499	≥500
1999	3348	4755	12 308	10 048	46 903	141 777
2000	3251	4732	9824	15 472	43 806	131 631
2001	1510	3188	7823	13 173	47 536	179 492
2002	1215	2475	9583	11 269	37 498	141 554
2003	1757	1900	7992	12 574	34 458	118 790
2004	1541	1415	7923	12 592	29 353	80 966
2005	1341	2153	6543	11 981	23 769	65 862
2006	505	2200	7905	6577	24 044	45 348
total	14 468	22 818	69 901	93 686	287 367	905 420

	Worked Hours					
Year	1–9	10–19	20–49	50–99	100–499	≥500
1999	79 783	183 880	839 619	761 356	4 778 611	12 861 750
2000	175 422	164 031	767 758	1 212 769	4 512 380	11 982 640
2001	63 654	204 159	688 551	769 283	3 740 067	11 577 285
2002	76 788	153 575	715 691	998 240	3 302 615	9 784 091
2003	66 338	152 578	529 969	841 758	3 125 267	8 831 090
2004	39 264	152 694	674 034	582 418	3 087 323	7 076 267
2005	46 661	298 114	467 478	966 063	4 711 932	7 262 752
2006	46 896	250 110	591 405	757 276	5 398 199	6 600 115
total	594 806	1 559 141	5 274 504	6 889 163	32 656 395	75 975 991

TABLE 11. Distribution of Gravity Index for Nonfatal Injuries by Size of Mine (1999–2006)

Year	Gravity Index						Spearman Correlation
	1–9	10–19	20–49	50–99	100–499	≥500	
1999	41.96	25.86	14.66	13.20	9.82	11.02	−.943
2000	18.53	28.85	12.80	12.76	9.71	10.99	−.886
2001	23.72	15.62	11.36	17.12	12.71	15.50	−.486
2002	15.82	16.12	13.39	11.29	11.35	14.47	−.543
2003	26.49	12.45	15.08	14.94	11.03	13.45	−.543
2004	39.25	9.27	11.75	21.62	9.51	11.44	−.314
2005	28.74	7.22	14.00	12.40	5.04	9.07	−.543
2006	10.77	8.80	13.37	8.69	4.45	6.87	−.771
M	24.32	14.63	13.25	13.60	8.80	11.92	−.886

workers) with the seriousness of the accidents. Table 9 shows the values of the ADI for six sizes of mines. Table 9 was calculated from the data in Table 8. There was no important variation between the different sizes of mines.

To obtain information about for the possible relationship between the seriousness of the accidents and the size of the mines, we calculated the gravity index for each group. Table 11 shows that index; it was developed from the data in Table 10.

Spearman correlation coefficients were lower than the critical value (.886), except in 1999, 2000, and the mean values in 1999–2006. This indicates a poor negative correlation between the size of the mine and the seriousness of the accidents, expressed as the gravity index. Furthermore, there is an important variation of the gravity index among the different sizes of mine. Thus, smaller mines had a greater proportion of accidents with more serious injuries. This coincides with Hunting and Weeks [13], Fabiano, Currò and Pastorino [19] and Saari [20].

4. CONCLUSIONS

We can draw the following conclusions.

- The incidence of work accidents in Spanish energetic mining decreases, whereas the age of the injured workers increases. However, the seriousness of the injuries caused by the accidents increases with age. Both results were significant. Using these results, the competent administrations and prevention services of the Spanish energetic mining sector should programme specific safety training and information for the youngest workers (especially those under 29 years). The causes of the most serious accidents of the oldest workers should also be analysed (especially those over 54 years). A possible explanation could be that the older workers take longer to recover from the same injuries than the younger ones.
- We did not observe any relationship between the seriousness of the accidents and the experience of the injured parties. The analysis was carried out for the seven most frequent kinds of accidents in underground and surface mining. There was a relationship between the seriousness of the accidents and the workers' occupational experience in accident type 50 (contact with a cutting, piercing, hard or rough agent) in underground mining only. Thus, the negative consequences of the accidents produced by type 50 decrease, whereas the workers' occupational experience increases.
- Accident 71 (physical overexertion of the musculoskeletal system) and 42 (being hit by a falling object or one that is detached) are the most frequent in underground and surface mining. Those two types of accidents caused the highest number of lost workdays, specifically, 242 713 and 16 377 lost workdays in underground and surface mining, respectively. It should be taken into account that in underground mining there is the highest ADI by the group of workers with more experience (>240 months), with values of 32.64 and 27.26 for accidents 42 and 71, respectively. Thus, in energetic underground mining for 1999–2008,

for workers with over 240 months of occupational experience (usually 40–45 years old), the results showed that the injuries caused by overexertion produced more lost workdays by the oldest workers. This is why people who are responsible for the organization of the work in different mines (underground and surface) in the Spanish energetic mining sector should consider the age of the workers who have to carry out specific jobs involving physical effort.

- The results seem to show that mining centres with a low number of workers had a higher incidence of accidents than those with more workers. This incidence is especially important in mines with under 10 workers, with an average risk index of 3.33 in 1999–2006.
- We cannot confirm that the seriousness of the accidents, expressed as ADI, increases or decreases with the size of the mining work centres, due to low statistical significance. However, if the seriousness of the accidents is expressed as a gravity index, the results indicate that the accidents in small mines are more serious. Thus, for 1999–2006, the average gravity index for energetic mining was 24.32 and 11.92, which corresponds with mines with ≤9 and ≥500 workers, respectively.

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