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Silicosis mortality in Italy: temporal trends 1990-2012 and spatial patterns 2000-2012

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Abstract

Introduction. The objective of this contribution is to describe, for the first time, occurrence, temporal trends and spatial patterns of mortality from silicosis in Italy in recent decades.

Methods. Mortality data on pneumoconiosis due to silica or silicates (ICD-9 code 502, ICD-10 code J62) were extracted from the Italian National Mortality Database. Temporal trends were analysed in the period 1990-2012; standardized rates per 100 000, spatial distribution, including cluster analysis, were computed for eleven years, i.e. 2000-2012 (2004-2005, data non available).

Results. In the period 1990-2012, a general decline in mortality was found with a total decrease of 74% and an estimated three year percentage change of -7.72. 4590 deaths from silicosis were observed in eleven years, 98% of them among men. The average age at death was 79.8 years. The mean age standardized rate was 0.33 (95% CI: 0.32 to 0.34). The Regions of Aosta Valley, Abruzzo and Sardinia had the highest rates. The assessment of risk at municipality level showed a significant excess of risk in 804 out of 8057 municipalities. Clusters of municipalities with a risk higher than expected were 34, observed in 18 out of 21 Regions.

Conclusions. The study shows that mortality due to silicosis in Italy has steadily declined in the last decades, with differences among Regions. Clusters of municipalities with an excess of risk should be verified with Local Health Units in order to assess the need of targeted preventive actions.

Key words
- silicosis
- mortality
- cluster analysis
- spatio temporal analysis
- risk assessment

INTRODUCTION

Silicosis is a world-wide occupational sclerogenic pneumoconiosis caused by prolonged intrapulmonary deposition of free crystalline silica particles according to a dose-dependent function [1]. Silica particles trigger a complex process leading to interstitial pulmonary fibrosis [2]; knowledge on this disease has been improving over time [3]. Silicosis may also develop and progress subsequently to the end of occupational exposure.

Crystalline silica shows a long biopersistence in the body, in particular in lungs, due to its chemical composition and insolubility in biological fluids. Cumulative dose of silica (concentration of respirable dust, multiplied by its content in crystalline silica, and for the duration of exposure), represents the most important risk factor.

Occupational exposure to respirable crystalline silica mainly occurs in a wide range of activities, namely in agriculture, mining, quarrying and related milling operations, construction, glass production (including fibreglass), cement production, abrasive production and use, ceramic industry, iron and steel mills, foundries, metal industry, shipbuilding and repair, rubber and plastic industry, automobile repair [4].

Silicosis latency can range from a few months to more than 30 years, depending on the physico-chemical characteristics of crystalline silica particles, on their concentration in the respirable fraction of the total dustiness, on the characteristics of the job at risk and on the clinical form of the disease. The latter has an influence on the median survival from diagnosis that ranges from 10 to 40 years.

Occupational crystalline silica exposure is associated with pulmonary tuberculosis, chronic obstructive pulmonary disease, lung cancer, autoimmune diseases (for example autoimmune vasculitis and renal autoimmune diseases) and silicosis [5].

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Silicosis is one of the most frequent occupational diseases in the world, particularly in rapidly industrializing countries such as China, Brazil, South Africa, and in low-income countries. However, precise estimates of exposure levels in these countries are not available at present. As for high income countries, a sharp reduction in the incidence of silicosis has been registered in the last decades. For example, in the United States (where at least 2.3 million workers have been estimated as potentially exposed to respirable crystalline silica in 2016 [6]) the number of deaths from silicosis has declined from 1065 in 1968 to 101 in 2010 [7, 8]. Despite the fact that reduced mortality rates were found in the US during 2001-2010 in subjects coded with silicosis as the underlying or contributing cause of death, no changes were observed in the age group 15-44 years [8].

A study conducted in 15 European countries for the estimation of the number of workers exposed to human carcinogens in the period 1990-1993, calculated that 3.2 million workers (280 000 in Italy) were exposed to crystalline silica [9]. The update of the same study for the period 2000-2003 showed for Italy an estimate of 250 000 workers exposed to silica [10]. According to an estimate by the Italian Workers Compensation Authority (INAIL), 29 000 workers were at high risk of exposure to silica in the period 2000-2004; these workers were mainly employed in construction/demolition processes, quarrying, metallurgy, and processing of non-metallic products, mostly in Sardinia, Liguria, Tuscany, Latium (especially in the province of Viterbo), and in the province of Trento [11]. In the period 2000-2004 INAIL ascertained 1003 cases of silicosis (96% men, 4% women), while in 2013 the cases of silicosis were 84 (82 men, 2 women) [12].

An Italian cohort mortality study conducted on 14 929 subjects ascertained as silicotics by INAIL, following national diagnostic criteria, showed that in 1335 cases (15.67%) silicosis was the underlying cause of death [13].

The aim of the present study is to investigate mortality from silicosis in Italy, with special reference to its temporal trends (1990-2012) and spatial patterns (2000-2012).

METHODS

Data source

Mortality data specific for all 8057 Italian municipalities were provided by the National Institute of Statistics (Istat). Population denominator are calculated every year by Istat as the average between two adjacent years. The underlying cause of death was coded using the 9th revision of the International Classification of Diseases until 2003 (ICD-9; pneumoconiosis due to other silica or silicates: code 502); since then ICD-10 has been used (pneumoconiosis due to other dust containing silica and pneumoconiosis due to talc dust: code J62). Data related to 2004-2005 are not available.

Indicators used for the analysis of mortality

Mortality rates and spatial analyses were computed for 2000-2012 using both a direct and an indirect standardization.

The direct method was used for calculating the age-standardised death rate (ASR) per 100 000, by age and gender, referring to the European standard population (ESP), an artificial population structure, updated by Eurostat (Statistical Institute of the European Union) in 2012 [14].

Trends of mortality (1990-2012) were evaluated at national level, and in Regions where the average rate values were higher than the national one; the ASR was calculated for three-year periods to reach a higher degree of robustness in computations.

Joinpoint regression analysis [15] was used to identify points where the linear slope of the trend (on a logarithmic scale) changed significantly. The estimated three-year percentage change (EAPC) was then calculated. Standardized mortality ratios (SMRs) were calculated for each of the 8057 Italian municipalities. The SMR for the period 2000-2012 was computed as the ratio of the number of observed deaths to the number of expected deaths. To compute SMR, the following five macro-areas were considered as reference: North-West (Piedmont, Lombardy, Liguria, Val d'Aosta); North-East (Veneto, Friuli-Venezia Giulia, Trentino-South Tyrol, Emilia-Romagna); Center (Tuscany, Umbria, Marche, Latium); South (Abruzzo, Molise, Campania, Apulia, Basilicata, Calabria) and Main Islands (Sicily and Sardinia). The age-specific SMR and their 95% confidence intervals (95% CI) were estimated either based on a Poisson distribution (if the observed deaths were fewer than 100) or using the Byar method (in case of more than 100 observed deaths).

Cluster analysis

Since death due to silicosis is rare, the expected mortality in many municipalities was very low; consequently, an SMR-based surveillance system could be affected by random variation and generate a number of positive signals by chance. For this reason and in order to determine whether concentrations of disease could be related to the geographic distribution of occupational exposure to silica, a municipal cluster analysis was carried out. The cluster analysis allows identifying areas with the highest variations from the expected figures as compared to values of the Region of reference. This approach was previously applied according to the spatial analysis of pleural mesothelioma risk associated with asbestos exposure [16]. This analysis was at first performed considering the 2000-2012 period, using the SatScan software (version 9.4.2, release date: July 2015) [17]. The procedure employs a circular or elliptical window of varying radius, from zero to some upper limit, which moves on the entire study area, centred at each step on one of the municipalities, identified by the x, y coordinates of the municipality's town hall. The method creates an infinite number of distinct geographical circles/ellipses with different sets of neighbouring data locations within them: each circle/ellipsis is a possible candidate for a cluster. Under the null hypothesis, the observed number of cases follows a uniform distribution, so that the expected number of cases in an area is proportional to its population size. The relative risk is the estimated risk within the cluster divided by the estimated risk outside the cluster. Since the phenomenon of mortality from silicosis was heterogeneously distributed on the territory, the maximum percentage of the "population" used to determine the maximum circle size of the scanning window was fixed to 30% of the total population of the Region of reference.

Average age at death from silicosis was calculated for Regions and Clusters.

RESULTS

Temporal trends (1990-2012)

The mean ASR for the entire period was 0.33 per 100 000 (95% CI: 0.32 to 0.34) overall, 0.86 for males and 0.01 for females. The mean ASR was 1.06 in the first three years (1990-1992) (95% CI: 1.01 to 1.10) and 0.22 in the last three years (2010-2012) (95% CI: 0.21 to 0.23), with a decrease of 74% (EAPC -7.72; 95% CI: -8.5 to -7.0) (*Figure 1*). The decrease in mortality varied depending on the geographic area: in Northern Italy the Joinpoint model, applied to the whole period, showed a descending trend in Aosta Valley Region, which was higher than the national level, with values of ASR from 13.95 (1992-1994) to 0.93 (2010-2012) and EAPC -12 (95% CI: -14.7 to -9.2); in Trento, ASR decreased less markedly shifting from 1.91 (1992-1994) to 0.34 in the last three year period (EAPC -6.77; 95% CI: -10 to -3.4); in Liguria ASR had a strong decrease until 1998 (EAPC -9.05; 95% CI: -17.9 to 0.7) and then it slowed down in the next time period (ASR = 1.31 in 1992-1994, ASR = 1.31 in 1996-1998, ASR = 0.56 in 2010-2012). In Central Italy, in Tuscany Region ASR decreased from 1.81 (1992-1994) to 0.51 in the last three year period (EAPC -6.3; 95% CI: -7.3 to -5.2). In Southern Italy, ASR was 4.1 in 1992-1994 and 1.03 in 2010-2012: in Calabria Region ASR was 1.71 in 1992-1994 and 0.54 in 2010-2012 (EAPC -7.9; 95% CI: -7.3 to -3.8); in the islands EAPC was -7.7 (95% CI: -3.8 to -7.3) in Sicily and -9.1 (95% CI: -10.5 to -7.7) in Sardinia with an ASR decreasing from 6.67 to 1.

Spatial patterns (2000-2012)

In the period 2000-2012, 4590 deaths for silicosis were registered, with a mean number of approximately 417 deaths per year; 4494 (98%) among men, only 96 among women (*Table 1*). The average age at death was 79.86 years: 98.2% after 65 years, 1.7% between 50 and 64 years, and only 0.1% of deaths occurred before the age of 49, with the youngest death occurred at 38 years of age. Some Regions showed higher rates as compared to the national average (*Table 2*) and some Regions had a slightly lower average age at death from silicosis than the Italian one (Friuli-Venezia Giulia 78.34; Molise 78.58; Campania 76.92 and Sicily 78.53). The very low portion of cases deceased in the age-group 50-64 were concentrated in few Regions (Lombardy, Liguria, Tuscany, Abruzzo, Calabria, Sicily and Sardinia).

The risk analysis (SMR) at municipal level showed significant excesses in 804 out of 8057 Italian municipalities (in the majority of cases the excess found consisted in a single death); the geographical distribution of death excesses was heterogeneous on the entire national territory (data not shown).

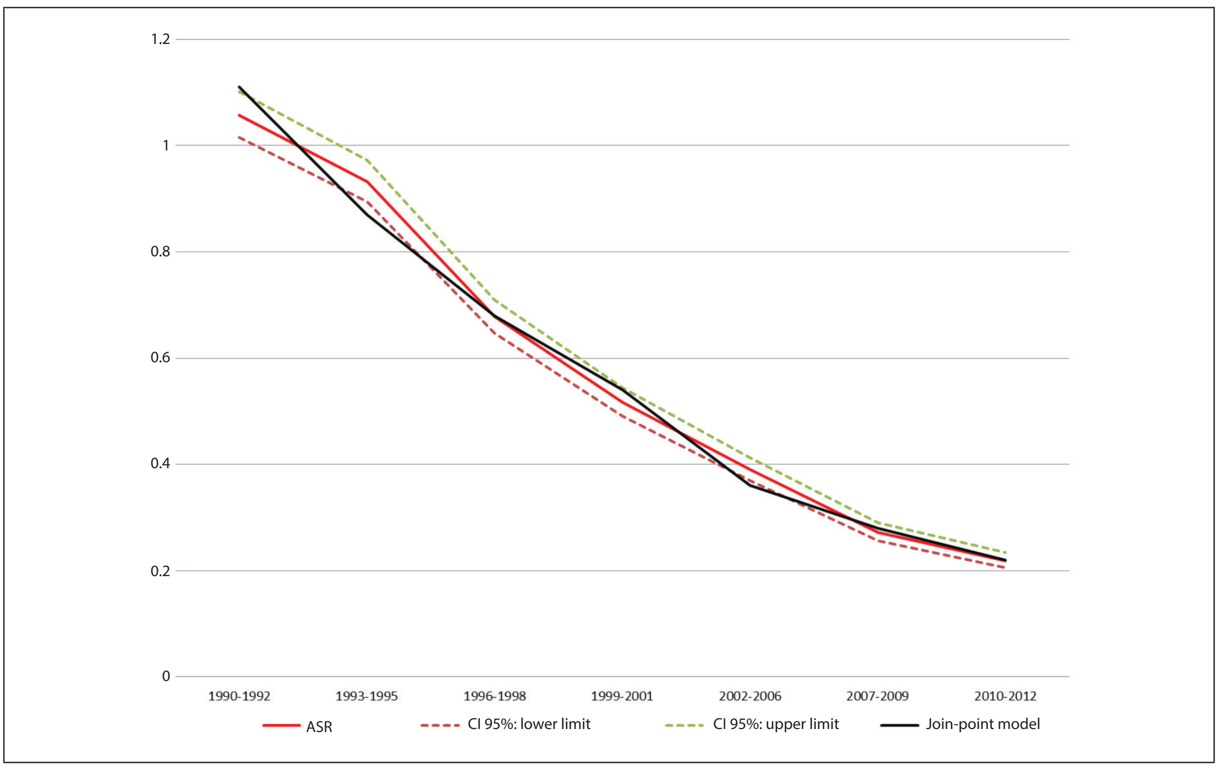

Figure 1
Trend in mortality from silicosis in Italy,1990-2012. Age-standardized rate (ASR) per 100 000 persons; Confidence Interval (CI) 95%, Join-point regression model.

Table 1
Silicosis mortality, 2000-2012. Age-group and gender-specific crude rates. Standardized mortality rates per 100 000 (Standard population: ESP)

	Men			Women			Total		
Age group	Observed cases	Crude rates	Standardized rates (CI 95%)	Observed cases	Crude rates	Standardized rates (CI 95%)	Observed cases	Crude rates	Standardized rates (CI 95%)
0-49 years	5	0.003	0.002 (0.001-0.006)	-	-	-	5	0.001	0.001 (0.000-0.003)
50-64 years	73	0.12	0.12 (0.09-0.15)	4	0.01	0.01 (0.002-0.02)	77	0.07	0.06 (0.05-0.08)
65+ years	4416	8.32	7.63 (7.41-7.87)	92	0.13	0.09 (0.08-0.12)	4508	3.55	2.90 (2.78-2.95)
Total	4494	1.45	0.86 (0.84-0.89)	96	0.03	0.01 (0.01-0.02)	4590	0.72	0.33 (0.32-0.34)

Table 2
Silicosis mortality, 2000-2012. Regional distribution. Standardized mortality rates per 100 000 (Standard population: ESP)

Region	Observed cases	Standardized rates (CI 95%)
Piedmont	203	0.17 (0.15-0.21)
Aosta Valley	48	1.50 (1.10-2.15)
Lombardy	350	0.16 (0.15-0.18)
Bolzano	25	0.25 (0.16-0.41)
Trento	79	0.67 (0.53-0.87)
Veneto	186	0.16 (0.14-0.19)
Friuli-Venezia Giulia	71	0.22 (0.17-0.30)
Liguria	411	0.75 (0.68-0.85)
Emilia-Romagna	122	0.10 (0.08-0.13)
Tuscany	747	0.68 (0.63-0.73)
Umbria	35	0.14 (0.09-0.22)
Marche	111	0.26 (0.21-0.32)
Latium	134	0.11 (0.10-0.14)
Abruzzo	513	1.53 (1.39-1.69)
Molise	12	0.15 (0.07-0.37)
Campania	48	0.05 (0.04-0.07)
Apulia	149	0.18 (0.15-0.21)
Basilicata	47	0.34 (0.25-0.50)
Calabria	352	0.82 (0.73-0.92)
Sicily	258	0.25 (0.22-0.29)
Sardinia	689	1.92 (1.77-2.08)
Italy	4590	0.33 (0.32-0.34)

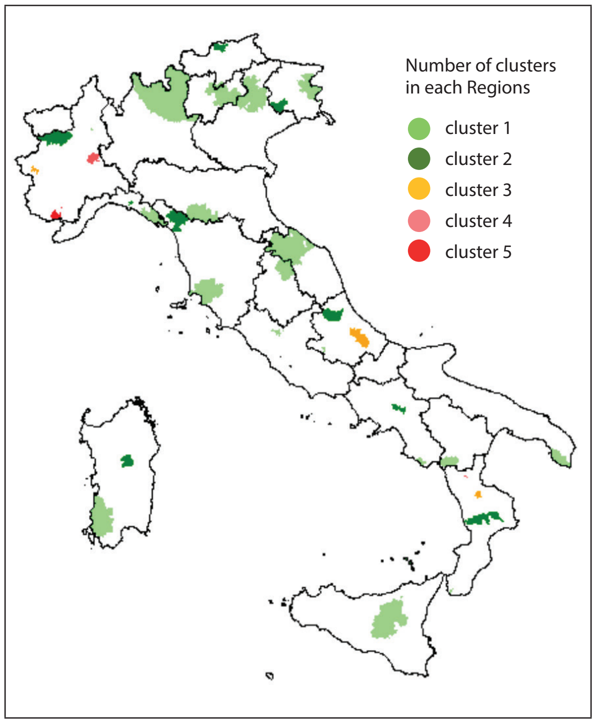

Figure 2
Mortality from silicosis in Italy, 2000-2012. Significant clusters (p-value < 0.05) in each Region.

Cluster analysis (2000-2012)

The cluster analysis method applied to each Region allowed identifying 34 geographic clusters of silicosis mortality in 18 out of 21 Regions (*Figure 2; Table 3a, 3b, 3c*).

Fifteen clusters were in Northern Italy, with 716 deaths found *vs* 128.9 expected; five clusters were in Central Italy (499 observed *vs* 70.02 expected deaths); fifteen clusters were found in Southern Italy and Islands (1218 observed *vs* 146.7 expected deaths).

DISCUSSION

This study describes silicosis mortality trends (1990-2012) and spatial patterns (2000-2012) in Italy. As in other high income industrialized countries, death rates have progressively declined over time. In Italy, however, many activities still involve potential occupational exposures: mining, digging and rock processing, production of ceramics, and the building sector, especially for renovations. Furthermore, high exposure levels have been recently reported in activities concerning the use and processing of synthetic materials containing large

Table 3a
Silicosis mortality, 2000-2012. Significant municipality clusters in Northern Italy. References: regional rates

Centroid	Radius/ semi-axis (km)[a]	Municipalities	p-value	Observed cases	Expected cases	Relative risk (CI 95%)	Average age
Piedmont							
1 Gattinara	1.8	2	< 0.001	14	0.44	31.77 (17.39-53.39)	80.5
2 Ronco Canavese	28.3/18.9	56	< 0.001	24	3.16	76.10 (48.66-11.30)	79.4
3 Salza di Pinerolo	6.9/4.6	3	< 0.001	6	0.07	88.63 (31.46-18.66)	81.5
4 Coniolo	10.2/6.8	14	< 0.001	17	2.59	6.57 (3.82-10.51)	80.4
5 Limone Piemonte	12.1	4	0.036	6	0.43	13.95 (5.12-30.37)	76.8
Lombardy							
1 Bormio	85.5	196	< 0.001	148	14.64	10.11 (85.34-11.89)	79.3
Liguria							
1 La Spezia	35.3	34	< 0.001	270	59.78	4.52 (3.99-5.09)	81.2
2 Cicagna	6.6/4.4	7	< 0.001	22	1.85	11.86 (7.45-18.00)	76.7
Trentino-South Tyrol							
1 Carzano	41.9/21	79	0.001	40	15.48	2.58 (1.85-3.52)	78.1
2 Racines	6.2	2	0.027	7	0.78	9.00 (3.61-18.49)	79.7
Veneto							
1 S. Gregorio nelle Alpi	30.2	56	< 0.001	69	12.85	5.37 (4.18-6.80)	80.5
Friuli-Venezia Giulia							
1 Pulfero	29.6/19.7	32	< 0.001	24	5.25	4.57 (2.93-6.80)	78
2 Pasiano di Pordenone	19.7/13.1	13	0.003	24	8.54	2.81 (1.80-4.18)	79.3
Emilia Romagna							
1 Lizzano in Belvedere	33.1/22.1	22	< 0.001	33	2.57	12.84 (8.83-18.03)	81.8
2 Novafeltria	9.3	5	< 0.001	12	0.44	27.43 (14.09-47.64)	80.5

[a]If the cluster is an ellipse to describe it in addition to the radius there is the value of the semi-axis.

Table 3b
Silicosis mortality, 2000-2012. Significant municipality clusters in Central Italy. References: regional rates

Centroid	Radius/ semi-axis (Km)[a]	Municipalities	p-value	Observed cases	Expected cases	Relative risk (CI 95%)	Average age
Tuscany							
1 Scarlino	33.1/22.1	10	< 0.001	234	22.7	10.31 (90.23-11.73)	82
2 Piazza al Serchio	22.5/15	17	< 0.001	146	12.23	11.94 (10.06-14.06)	79.8
Umbria							
1 Costacciaro	21	7	< 0.001	20	2.46	8.14 (4.97-12.56)	80
Marche							
1 Auditore	54	71	< 0.001	65	31.88	2.04 (1.57-2.60)	79.5
Latium							
1 Civita Castellana	10.4/7	6	< 0.001	34	0.75	45.26 (31.39-63.35)	77.8

[a]If the cluster is an ellipse to describe it in addition to the radius there is the value of the semi-axis.

amounts of crystalline silica [18, 19]. These scenarios have taken place in the absence of regulation about exposure levels, since only recently the EU has started to consider the introduction of a limit value in the working environment for dust containing free crystalline silica. Even though it is not possible to make direct comparisons, due to differences in health regulation or other factors such as in rates calculations (i.e. different reference populations), the total number of cases in Italy appears to be one order of magnitude higher than that observed in the US and UK [8, 20, 21]. The authors cannot exclude that Italy's excess of silicosis as underly-

Table 3c
Silicosis mortality, 2000-2012. Significant municipality clusters in Southern Italy and the Islands. References: regional rates

Centroid	Radius/ semi-axis (km)[a]	Municipalities	p-value	Observed cases	Expected cases	Relative risk (CI 95%)	Average age
Abruzzi							
1 Capistrello	0	1	< 0.001	62	1.84	33.75 (25.83-43.19)	76.8
2 Tossicia	16.7/11.1	15	< 0.001	104	13.67	7.61 (6.20-9.24)	79.8
3 Pennapiedimonte	25.5/8.5	28	< 0.001	90	28.19	3.19 (2.57-3.92)	81.1
Campania							
1 Centola	10.7/7.1	4	< 0.001	9	0.13	67.51 (31.66-13.14)	75.1
2 Lapio	14.3/4.8	18	< 0.001	13	0.53	24.47 (13.57-43.59)	78.4
Apulia							
1 Ugento	23.6/15.7	25	< 0.001	80	8.04	9.95 (7.89-12.38)	79.5
Basilicata							
1 Lauria	14.3/9.5	7	< 0.001	38	2.47	15.38 (10.89-21.12)	78.4
Calabria							
1 Motta S. Giovanni	0	1	< 0.001	91	1.18	76.85 (62.09-94.69)	79.4
2 Colosimi	35/8.8	25	< 0.001	96	10.94	8.77 (7.11-10.72)	77.6
3 Acri	0	1	< 0.001	40	3.95	10.13 (7.23-13.79)	78.6
4 San Basile	0	1	< 0.001	10	0.36	27.90 (13.32-51.08)	80.4
Sicily							
1 Assoro	37.5/25	25	< 0.001	113	10.74	10.52 (8.65-12.67)	79
2 Ustica	162.9/54.3	5	< 0.001	27	0.67	40.34 (26.56-58.63)	78.3
Sardinia							
1 Buggerru	44/29.3	22	< 0.001	427	60.49	7.06 (6.40-7.76)	81.3
2 Orotelli	11.7/7.8	4	0.004	18	4.20	4.29 (2.54-6.77)	78.4

[a]If the cluster is an ellipse to describe it in addition to the radius there is the value of the semi-axis.

ing cause of death could be partially due to the misuse of criteria for silicosis ascertainment when the worker is still alive.

While mortality from silicosis has dramatically dropped down in recent years in most Italian Regions, in Liguria [11], Sardinia and Abruzzo, standardized rates are still close to 2 cases per 100 000 individuals per year. These Regions are included by INAIL among the top five Italian Regions in terms of risks for workers. The average age at death from silicosis in these Regions is around 80 years, in line with the general national mortality. In some Regions there are still slight concentrations of cases in younger age groups, that definitely require a special focus.

For some of the clusters it is possible to identify local occupational activities at risk of respirable silica dust exposure [11, 22].

In fact, the historical presence of mining activities can be found in many important clusters, as in Piedmont in the Canavese area (mining and processing of gneiss rock, with over 30% of silica and talc) and in Chisone Valley (graphite extraction, talc mining and milling) [23]; in Lombardy in Bormio (quarries of quartzite and granite, both rocks with a high silica content, and gneiss); in Trentino-South Tyrol (porphyry quarries, with a silica content equal to 30-35%); in Tuscany in Scarlino (processing of titanium minerals) and Piazza al Serchio (silver mines); in Marche (sulphur removal); in Apulia (extraction of bauxite at Ugento); in Sicily (sulphur mine in Assoro); in Sardinia (coal mining in Buggerru, bauxite and granite in Orotelli [24, 25]). The cluster of Civita Castellana (Viterbo) is associated with the production of ceramics, since several medium-sized industries that produce bathroom fixtures and kitchenware using raw materials with high content of silica (clay, feldspar, quartz) are located in the area. A significant incidence of silicosis has been observed for decades in Civita Castellana [26, 27].

The presence of areas at higher risk could be due to the concurrence of occupational exposure and inadequate preventive activities. Furthermore, in some areas mortality from silicosis could be over-diagnosed due to local sensitivity to social security aspects issues, as the ascertained cases of silicosis fall in the category of occupational diseases.

The present approach does not allow to assess with certainty the risk of silicosis due to frequent and widespread activities that imply exposure to silica, like those in the building sector. Indeed, our results in some way might show the consequence of exposures occurred mainly in the '70s and '80s, with special reference to fairly well localized activities such as quarries, excavation of hydroelectric and highway tunnels, and foundries.

Mortality is not the best indicator of silicosis occurrence, since the disease is usually chronic and it is not always registered as the underlying cause of death. This could result in an underestimation of the disease, even if it is not likely that the phenomenon might affect the temporal and spatial analyses, unless mortality certifications were differential in time or in space. This hypothesis, however, is not supported by available evidence.

Mortality due to silicosis is a rare event and exposure to silica can lead to the onset of a variety of symptoms/diseases that can eventually be causes of death. A study on these mortality causes could lead to a better knowledge of the epidemiological framework of those clusters with no available evidence of local exposure so far [22, 28].

CONCLUSIONS

The present study shows that mortality due to silicosis has steadily declined in the last decades but it is still not eradicated. One of its main features is regional variability, due to the presence or absence of sources of exposure and to different exposure levels in the various areas, but also partially due to possible different interpretations at regional level of the national guidelines for ascertainment of occupational diseases.

As for the estimation of exposure levels, a general remark should be done about the lack of reliable information throughout the national territory.

In this frame, the present paper contributes to achieving a better insight of the occurrence of silicosis in Italy. For an even better perspective, though, a collective effort of Regional and Local Health Authorities is required. As much as the network of Occupational Health Units of the National Health Service that are scattered all over the country will check the current and past silica exposure patterns within the geographic areas for which they are entitled, it will be possible to track relevant sources of exposure and implement targeted preventive actions, in order to prevent new cases of silicosis.

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Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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REFERENCES

1. Turci F, Pavan C, Leinardi R, Tomatis M, Pastero L, Garry D, *et al.* Revisiting the paradigm of silica pathogenicity with synthetic quartz crystals: the role of crystallinity and surface disorder. *Particle Fibre Toxicology* 2015;13(1):32. DOI:10.1186/s12989-016-0136-6
2. Baldasseroni A, Carnevale F. The genesis and development of the scientific concept of pulmonary silicosis during the nineteenth century. In: Rosenthal PA (Ed). *Silicosis: A world history*. Baltimore: Johns Hopkins University Press; 2004.
3. Di Lorenzo L. Patologie respiratorie. Silicosi. In: Alessio L, Franco G, Tomei F (Eds). *Trattato di Medicina del Lavoro*. Padova: Piccin; 2015.
4. International Agency for Research on Cancer. *Silica dust, crystalline, in the form of quartz or cristobalite*. IARC Monographs No. 118C. Lyon, France: IARC; 2012.
5. World Health Organization. Crystalline silica, quartz. *Concise International Chemical Assessment Document (CICAD)* No. 24. Geneva: WHO; 2000.
6. US Occupational Safety and Health administration. Occupational exposure to respirable crystalline silica. Final Rule. 29 CFR Parts 1910, 1915, and 1926. *Fed Reg* 2016;81(58):16285-90. Available from: www.gpo.gov/fdsys/pkg/FR-2016-03-25/pdf/2016-04800.pdf.
7. Mazurek JM, Attfield MD. Silicosis mortality among young adults in the United States, 1968-2004. *Am J Ind Med* 2008;51:568-78.
8. Bang KM, Mazurek JM, Wood JM, White GE, Hendricks SA, Weston A. Silicosis mortality trends and new exposures to respirable crystalline silica, United States, 2001-010. *MMWR* 2015;64:117-20.
9. Kauppinen T, Toikkanen J, Pedersen D, Young R, Ahrens W, Boffetta P, *et al.* Occupational exposure to carcinogens in the European Union. *Occup Environ Med* 2000;57(1):10-8.
10. Mirabelli D, Kauppinen T. Occupational exposures to carcinogens in Italy: an update of CAREX database. *Int J Occup Environ Health* 2005;11(1):53-63.
11. Scarselli A, Binazzi A, Marinaccio A. Occupational exposure to crystalline silica: estimating the number of workers potentially at high risk in Italy. *Am J Ind Med* 2008;51(12):941-9. DOI: 10.1002/ajim.20619.
12. Istituto Nazionale Assicurazione Infortuni (INAIL). *Banca dati e statistiche*. Available from: www.inail.it/internet/default/Statistiche/Bancadatistatistica/index.html.
13. Marinaccio A, Scarselli A, Gorini G, Chellini E, Mastrantonio M, Uccelli R, *et al.* Retrospective mortality cohort study of Italian workers compensated for silicosis. *Occup Environ Med* 2006;63(11):762-5.
14. Office for National Statistics (UK). *Revised European Standard Population 2013 (2013 ESP).* Available from: www.ons.gov.uk/ons/guide-method/user-guidance/health-and-life-events/revised-european-standard-population-2013--2013-esp-/index.html.
15. Joinpoint software. Available from: https://surveillance.cancer.gov/joinpoint/. 16. McCullagh P, Nelder JA. *Generalized Linear Models*. 2nd Edition. Dordrecht, Netherlands: Springer Science + Business Media BV; 1989.
16. Fazzo L, Minelli G, De Santis M, Bruno C, Zona A, Marinaccio A, *et al.* Mesothelioma mortality surveillance and asbestos exposure tracking (in Italian). *Ann Ist Super Sanità* 2012;48(3):300-10.
17. Kulldorff M. A spatial scan statistic. *Commun Stat Theory Methods* 1997;26(6):1481-96. DOI: 10.1080/03610929708831995

18. Bartoli D, Banchi B, Di Benedetto F, Farina GA, Iaia TE, Poli C, *et al.* Silicosis in employees in the processing of kitchen, bar and shop countertops made from quartz resin composite. Provisional results of the environmental and health survey conducted within the territory of USL 11 of Empoli in Tuscany among employees in the processing of quartz resin composite materials and review of the literature. *Ital J Occup Environ Hyg* 2012;3:138-43. Italian.
19. Pèrez-Alonso A, Còrdoba-Doňa JA, Millares-Lorenzo JL, Figuera-Murillo E, Garcia Vadillo C, Romero-Murillo J. Outbreak of silicosis in Spanish quartz conglomerate workers. *Int J Occup Environ Environ Health* 2014;20:26-32.
20. Health and Safety Executive, UK. Pneumoconiosis. New cases assessed by year, agent, percentage disablement and age (2006 to latest year). Available from: www.hse.gov.uk/statistics/tables/iidb07.xlsx.
21. Mazurek JM, Schleiff PL, Wood JM, Hendricks SA, Weston A. Notes from the Field: Update: Silicosis Mortality, United States, 1999-2013. *MMWR* 2015;64(23);653-4.
22. Scarselli A, Binazzi A, Forastiere F, Cavariani F, Marinaccio A. Industry and job-specific mortality after occupational exposure to silica dust. *Occup Med* 2011;61(6):422-9.
23. Coggiola M, Bosio D, Pira E, Piolatto PG, La Vecchia C, Negri E, *et al.* An update of a mortality study of talc miners and millers in Italy. *Am J Ind Med* 2003;44(1):63-9.
24. Carta P, Cocco PL, Casula D. Mortality from lung cancer among Sardinian patients with silicosis. *Br J Ind Med* 1991;48(2):122-9.
25. Carta P, Aru G, Manca P. Mortality from lung cancer among silicotic patients in Sardinia: an update study with 10 more years of follow up. *Occup Environ Med* 2001;58(12):786-93.
26. Forastiere F, Lagorio S, Michelozzi P, Cavariani F, Arcà M, Borgia P, *et al.* Silica, silicosis and lung cancer among ceramic workers: a case-referent study. *Am J Ind Med* 1986; 10(4):363-70.
27. Cavariani F, Carneiro AP, Leonori R, Bedini L, Quercia A, Forastiere F. Silica in ceramic industry: exposition and pulmonary diseases (in Italian). *G Ital Med Lav Ergon* 2005;27(3):300-2.
28. Forastiere F, Lagorio S, Michelozzi P, Perucci C, Axelson O. Mortality Pattern of silicotic subject in the Latium region, Italy. *Br J Ind Med* 1989;46(12):877-80.