SHORT REPORT

Saharan dust and the association between particulate matter and daily hospitalisations in Rome, Italy

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ABSTRACT

Introduction Outbreaks of Saharan dust have been shown to exacerbate the effect of particulate matter (PM) on mortality. Their role on PM–morbidity association is less clear. This study aims to evaluate the effect of Saharan dust on the PM–hospitalisations association in Rome, Italy.

Methods We studied residents hospitalised in Rome between 2001 and 2004 and performed a time-series analysis to explore the effects of $PM_{2.5}$, $PM_{2.5–10}$ and PM_{10} on cardiac, cerebrovascular and respiratory emergency hospitalisations, respectively. Saharan dust days were identified by combining Light Detection and Ranging observations and analyses from operational models. We tested a dust–PM interaction to evaluate the hypothesis that the PM effect on hospitalisations would be enhanced on dust days.

Results We studied 77 354, 26 557 and 31 620 hospitalisations for cardiac, cerebrovascular and respiratory diseases, respectively, providing effect estimates per IQR. $PM_{2.5–10}$ was associated with cardiac diseases (3.93%; 95% CI 1.58 to 6.34). PM_{10} was associated with cardiac (3.37%; 95% CI 1.11 to 5.68), cerebrovascular (2.64%; 95% CI 0.06 to 5.29) and respiratory diseases (3.59%: 95% CI 0.18 to 7.12). No effect of $PM_{2.5}$ was detected. Saharan dust modified the effect of the $PM_{2.5–10}$ on respiratory hospitalisations, higher during dust days compared with dust-free days (14.63% vs −0.32%; p value of interaction=0.006). Saharan dust also increased the effect of PM_{10} on cerebrovascular diseases (5.04% vs 0.90%, p value of interaction=0.143).

Discussion A clear enhanced effect of $PM_{2.5–10}$ on respiratory diseases and of PM_{10} on cerebrovascular diseases emerged during Saharan dust outbreaks.

What this paper adds

- Evidence of the impact of Saharan dust events on human health is limited, and findings from the available studies are controversial.
- This study addressed the hypothesis that the particulate matter (PM) effect on morbidity would be enhanced on dust days as well as what we already observed in Rome for mortality.
- We found strong effects of $PM_{2.5–10}$ on cardiac hospitalizations and of PM_{10} on cardiac, cerebrovascular and respiratory hospitalisations, even though not modified by Saharan dust.
- The effect of $PM_{2.5–10}$ on respiratory hospitalisations was strong and clearly enhanced during Saharan dust advection days.
- The role of Saharan dust should be re-evaluated in order to better address the objectives and strategies of a new European directive on ambient air quality.

INTRODUCTION

Winds from the Sahara–Sahel desert regions transport large amounts of dust from North Africa to the Euro-Mediterranean areas. Saharan dust advection days have been shown to contribute to particulate matter (PM_{10}) (mass concentration of PM with aerodynamic diameter <10 μm) exceeding the daily European Union- and WHO-recommended limits.[1]

To date, evidence of the impact of Saharan dust events on health is still limited. Conflicting results have been reported in studies on the effects of Saharan advection events on mortality.[2] Few studies have reported health effects of Saharan dust on daily morbidity.[2–6] On the other hand, the issue is under debate in the European Commission because revised air quality standards are foreseen, and it is not yet agreed whether dust from natural sources should be monitored and to what extent limit values should be applied.

The aim of this study is to evaluate the associations between various particle fractions and daily hospitalisations in Rome, Italy, for cardiac, cerebrovascular and respiratory diseases, and the effect modification of Saharan dust advection on these associations.

METHODS

Daily data of hospital admissions were collected for residents in Rome between 2001 and 2004 from the datasets of the Lazio Regional Public Health Agency. Only emergency hospitalisations of people aged less than 14 years or 35 years or more were analysed. Daily counts of hospital admissions for cardiac (International Classification of Diseases, 9th revision–ICD9: 390–429), cerebrovascular (ICD9: 430–438) and respiratory (ICD9:460–519) diseases were selected based on the primary diagnosis defined at discharge.

Environmental data were provided by the monitoring network of the Lazio Environmental Protection Agency. $PM_{2.5}$ (PM with aerodynamic diameter <2.5 μm) and PM_{10} data were obtained from a population-oriented monitoring station on

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the grounds of the Italian National Institute of Health. Daily average concentrations of PM_{10} and a maximum running means of O_3 daily for 8 h during the warm season (April–September) were also computed from hourly measures at three fixed urban background stations. $PM_{2.5–10}$ (coarse fraction) concentrations were computed as differences between 24-hour mean values of PM_{10} and $PM_{2.5}$ at the same monitoring station. Daily meteorological data were obtained from the Italian Air Force Meteorological Service.

Saharan dust days were identified by combining Light Detection and Ranging (laser radar) observations and analyses from operational models. The outputs of this modelling provide whether a dust event is occurring over the city, and the calculation of the PM_{10}:NO_2 ratio is an index of the Saharan dust reaching the ground level[7] (further details are provided in the online supplementary material).

A time-series analysis using generalised additive models was performed. The PM–hospitalisation association was estimated by using an overdispersed Poisson regression model. Time trend and seasonality were adjusted for by introducing a three-way interaction between day of the week, month and year. This makes our regression model comparable with the time-stratified case-crossover design.[8] The model was adjusted for potential confounders: temperature, barometric pressure, indicators of population decrease and influenza epidemics. The temperature confounding effect was controlled by including two penalised splines in the model, corresponding to the cold (at lag 1–6 of air temperature) and warm (at lag 0–1 of apparent temperatures) temperatures.

The average concentrations of PM_{10}, $PM_{2.5–10}$ and $PM_{2.5}$ at lag 0–1 for cardiac diseases, at lag 0 for cerebrovascular diseases and at lag 0–5 for respiratory diseases, were chosen as the main exposure time scales. In addition, we performed analyses of immediate (lag 0–1), delayed (lag 2–5) and prolonged (lag 0–5) effects.[7 9] Effect estimates were obtained from single pollutant models as well as bi-pollutant models, fitting $PM_{2.5}$ and $PM_{2.5–10}$ simultaneously.

The effect modification of Saharan dust advection on the PM–morbidity association was evaluated by including an interaction term between the dichotomous dust index and the exposure variable. The effects are reported as percent increases in the risk (IR%) of hospitalisations associated with an IQR increase for each pollutant and the correspondent 95% CI. Two sensitivity analyses were performed considering the potential confounding effect of O_3 during the warm season and excluding the year 2003 characterised by frequent heat waves. All statistical analyses were performed by using the libraries *mgcv* and *splines* from the R software V.2.14.1.[10]

RESULTS

About 19% of days between 2001 and 2004 were affected by Saharan dust reaching ground level in Rome, with a higher frequency during warmer seasons. The mean concentration of particles was higher during dust days than during dust-free days, with higher excesses for coarse than for fine particles. The mean daily concentrations of PM_{10} were 37.0 $\mu g/m^3$ and 52.2 $\mu g/m^3$ (Student's t test, p=0.001) during dust-free and dust-affected days, respectively. The means of $PM_{2.5}$ were 23.4 $\mu g/m^3$ and 25.6 $\mu g/m^3$ (p=0.0168), and the means of $PM_{2.5–10}$ were 14.6 $\mu g/m^3$ and 20.7 $\mu g/m^3$ (p=0.001). Also O_3, air temperature and apparent temperature were higher during dust days than during dust-free days (p=0.001). $PM_{2.5}$ and $PM_{2.5–10}$ were moderately correlated (Pearson's correlation coefficient=0.25), whereas $PM_{2.5}$–PM_{10} and $PM_{2.5–10}$–PM_{10} correlations were very high (r=0.628 and r=0.831, respectively).

The number of hospitalisations was 77 354 for cardiac, 26 557 for cerebrovascular and 31 620 for respiratory diseases. The mean daily number of hospitalisations was similar on dust-affected and dust-free days, but cardiac and respiratory hospitalisations were higher during dust-affected than during dust-free days in spring (p=0.024 and p=0.009 for cardiac and respiratory diseases, respectively) and summer (p=0.116 and p=0.012, respectively).

Positive and statistically significant associations were found between $PM_{2.5–10}$ (IQR 10.8 $\mu g/m^3$) and cardiac diseases (for lag 0–1, 3.93%, 95% CI 1.58 to 6.34), and between PM_{10} (IQR 19.8 $\mu g/m^3$) and cardiac, cerebrovascular and respiratory diseases (for lag 0–1, 3.37%, 95% CI 1.11 to 5.68; for lag 0, 2.64%, 95% CI 0.06 to 5.29; for lag 0–5, 3.59%, 95% CI 0.18 to 7.12, respectively). No significant effect was detected between $PM_{2.5}$ and either group of hospitalisations. Effect modification of Saharan dust advection on the association between hospitalisations and particles was seen for respiratory diseases, with effects of $PM_{2.5–10}$ (14.62% vs −0.32, p value of interaction=0.006). Effect modification of Saharan dust was also found for PM_{10} and cerebrovascular diseases (5.04% during dust-affected days vs 0.90% during dust-free days, p value of interaction=0.143) (table 1). Effect estimates at different cumulated lags for all the outcomes are reported in the online supplementary material (see online supplementary tables S1, tS2, and tS3). The health effects of $PM_{2.5}$ and $PM_{2.5–10}$ did not change when both pollutants were included in the models (see online supplementary table S4). All main results were robust to O_3 adjustment (results not shown) and to the exclusion of the year 2003 (see online supplementary table S5); the only exception was seen for the year 2003 analysis where a significant effect modification of Saharan dust advection on the $PM_{2.5–10}$–respiratory hospitalisations association was found for children (p value of interaction=0.039).

DISCUSSION

We found effects of $PM_{2.5–10}$ on cardiac hospitalisations and of PM_{10} on cardiac, cerebrovascular and respiratory diseases. No $PM_{2.5}$ effect was found. Saharan dust events enhanced the risk of respiratory and cerebrovascular admissions associated with $PM_{2.5–10}$ and PM_{10}, respectively. No $PM_{2.5}$ effect modification was found during Saharan dust-affected days. These results are complementary to those of our previous study on mortality,[7] for which we identified an important effect modification of Saharan dust on the association between $PM_{2.5–10}$ and cardiac mortality, and to a lesser extent $PM_{2.5–10}$ and respiratory mortality.

Few epidemiological studies investigated the effect modification of Saharan dust on the PM–morbidity association.[2–6] Middleton *et al*,[3] in Cyprus, found that admissions associated to PM_{10} increased during dust-affected days, more for cardiovascular (10.4% increase) and less for respiratory diseases (3.1% increase) than those observed in Rome. Samoli *et al*[4] reported higher admissions associated to PM_{10} for paediatric asthma exacerbation during Saharan dust episodes, but the effect of modification was not statistically significant. In Hong Kong, Tam *et al*[5] found a 2% increase in cardiovascular admissions associated with $PM_{2.5–10}$ during dust-affected versus dust-free days, whereas we found in Rome no modification of the effect of $PM_{2.5–10}$ on cardiac and cerebrovascular hospitalisations. The PM_{10}–respiratory admission association observed by Tam *et al*[6] (RR=1.05) during dust-affected days is consistent with our findings (%IR=5.04). Despite substantial differences in the study

Table 1 Association between PM and hospitalisations: percent increase in risk (IR%) of hospital admissions and 95% CI, associated with IQR increases in different particulate matter (PM) fractions due to hospitalisation and the presence or absence of Saharan dust

Cause	$PM_{2.5}$ (IQR=12.8 μg/m³) IR% (95% CI)	p-Interaction*	$PM_{2.5-10}$ (IQR=10.8 μg/m³) IR% (95% CI)	p-Interaction*	PM_{10} (IQR=19.8 μg/m³) IR% (95% CI)	p-Interaction*
Cardiac diseases (lag 0–1) (ICD9: 390–429)	2.41 (−0.21 to 5.09)		3.93 (1.58 to 6.34)		3.37 (1.11 to 5.68)	
Saharan dust-free days	1.93 (−0.82 to 4.76)	–	3.83 (0.77 to 6.98)	–	2.77 (0.06 to 5.55)	–
Saharan dust-affected days	5.07 (−1.61 to 12.21)	0.378	4.03 (0.26 to 7.94)	0.934	3.30 (−1.24 to 8.06)	0.841
Cerebrovascular diseases (lag 0) (ICD9: 430–438)	−2.14 (−4.73 to 0.53)		1.68 (−0.70 to 4.11)		2.64 (0.06 to 5.29)	
Saharan dust-free days	−2.85 (−5.62 to 0.00)	–	1.20 (−1.98 to 4.49)	–	0.90 (−2.34 to 4.25)	–
Saharan dust-affected days	0.93 (−5.16 to 7.42)	0.250	1.86 (−1.85 to 5.72)	0.792	5.04 (0.39 to 9.91)	0.143
Diseases of the respiratory system (lag 0–5) (ICD9: 460–519)	−0.52 (−5.33 to 4.53)		4.77 (−0.57 to 10.40)		3.59 (0.18 to 7.12)	
Saharan dust-free days	−1.03 (−6.18 to 4.40)	–	−0.32 (−6.33 to 6.07)	–	3.00 (−0.70 to 6.85)	–
Saharan dust-affected days	−1.45 (−11.58 to 9.85)	0.942	14.62 (5.34 to 24.72)	0.006	4.40 (−3.74 to 13.22)	0.760
Diseases of the respiratory system 0–14 (lag 0–5) (ICD9: 460–519)	−2.14 (−9.09 to 5.35)		−1.20 (−8.52 to 6.71)		−0.04 (−4.64 to 4.78)	
Saharan dust-free days	−3.30 (−10.56 to 4.55)	–	−4.71 (−13.07 to 4.46)	–	0.23 (−4.84 to 5.56)	–
Saharan dust-affected days	−1.50 (−16.59 to 16.31)	0.833	2.87 (−9.10 to 16.41)	0.299	−2.10 (−12.98 to 10.14)	0.712

*p Value of interaction term PM×Dust Index.

designs, all studies on PM–morbidity association pointed towards enhanced harmful effects of particles (except the fine fraction) on dust-affected days.

An issue related to health effects of Saharan dust, not covered in our study but under a scientific debate, is that concerning the PM components of Saharan dust responsible for enhanced effect of the coarse fraction. A higher content of viruses, bacteria and fungi,[11] as well as a different composition of the anthropogenic pollutants, collected during the long-range transport, could be responsible for a stronger inflammatory reaction and oxidative stress at cellular level. A recent study on cardiovascular mortality in Barcelona, Spain,[12] addressed this issue indirectly by decomposing daily PM concentrations during Saharan dust days in local and Saharan contributions. The authors found a relevant effect of both components during Saharan dust days, suggesting that human-made particulate can also be more toxic on Saharan dust-affected days.

We do not have complete data on specific PM components in Rome. Moreover, the small number of Saharan dust-affected days prevented to analyse the effect modification related to individual factors such as age, gender and previous comorbidities.

In conclusion, our study found an enhanced effect of the $PM_{2.5-10}$ on respiratory diseases and of PM_{10} on cerebrovascular morbidity during Saharan dust-affected days. This suggests a specific contribution of Saharan dust composition to the toxicity of $PM_{2.5-10}$ and PM_{10}. Further studies should pay special attention to the role of characteristics, composition and toxicity of dust particles from long-range transport.

Contributors ERA and MS designed the study, conducted the analyses and drafted the manuscript. AF and FF conceived the study design. GPG provided data on Saharan dust and revised the manuscript. All the authors commented critically on the initial draft and have agreed with the final text.

Competing interests None.

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REFERENCES

1 Matassoni L, Pratesi G, Centioli D, *et al*. Saharan dust episodes in Italy: influence on PM10 daily limit value (DLV) exceedances and the related synoptic. *J Environ Monit* 2009;11:1586–94.
2 Karanasiou A, Moreno N, Moreno T, *et al*. Health effects from Saharan dust episodes in Europe: literature review and research gaps. *Environ Int* 2012;47:107–14.
3 Middleton N, Panayotis Y, Kleanthous S, *et al*. A 10-years time-series analysis of respiratory and cardiovascular morbidity in Nicosia, Cyprus: the effect of short term changes in air pollution and dust storms. *Environ health* 2008;7:39.
4 Samoli E, Nastios PT, Paliatsos AG, *et al*. Acute effects of air pollution on pediatric asthma exacerbation: evidence of association and effect modification. *Environ Res* 2011;111:418–24.
5 Tam WWS, Wong TW, Wong AHS. Effect of dust storm events on daily emergency admissions for cardiovascular diseases. *Circ J* 2012;76:655–60.
6 Tam WWS, Wong TW, Wong AHS, *et al*. Effect of dust storm events on daily emergency admissions for respiratory diseases. *Respirology* 2012;17:143–8.
7 Mallone S, Stafoggia M, Faustini A, *et al*. Saharan dust and associations between particulate matter and daily mortality in Rome, Italy. *Environ Health Perspect* 2011;119:1409–14.
8 Lu Y, Zeger SL. On the equivalence of case-crossover and time-series methods in environmental epidemiology. *Biostatistics* 2007;8:337–44.
9 Berti G, Galassi C, Faustini A, *et al*. EPIAIR Inquinamento atmosferico e salute. Sorveglianza epidemiologica e interventi di prevenzione. *Epidemiol Prev* 2009;33, nov–dec suppl 1: 1–144.
10 R Development Core Team. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing, 2011.
11 Sandström T, Forsberg B. Desert dust: an unrecognized source of dangerous air pollution? *Epidemiology* 2008;19:808–9.
12 Perez L, Tobias A, Pey J, *et al*. Effects of local and Saharan particles on cardiovascular disease mortality. *Epidemiology* 2012;23:768–9.