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Long-Term Effects of Ambient PM2.5 on Cardiovascular and Kidney Outcomes in a Nationwide Cohort of Over Two Million

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Objectives : Ambient fine particulate matter ($PM_{2.5}$) is a major environmental risk factor for cardiovascular morbidity and mortality worldwide. Emerging evidence suggests that $PM_{2.5}$ may also adversely affect kidney health and related outcomes; however, whether individuals with chronic kidney disease (CKD) exhibit greater susceptibility to these effects remains uncertain.
Methods : We conducted a nationwide matched cohort study using the Korean National Health Insurance database linked to district-level $PM_{2.5}$ prediction models. We identified 1,077,740 adults with CKD who had no prior cardiovascular or kidney-related hospitalizations and matched them 1:1 with individuals without CKD by age, sex, and income. Long-term exposure to $PM_{2.5}$ was defined as a two-year moving average (lag 0–1). Time-varying Cox models estimated hazard ratios per 10 μg/m³ increase in $PM_{2.5}$ for major adverse cardiovascular events (MACE) and kidney-related outcomes. Multipollutant models including NO_2 and ozone were also evaluated.
Results : Over a mean follow-up of 8.4 years, each 10 μg/m³ increase in long-term $PM_{2.5}$ exposure was associated with an increased risk of MACE in both CKD (hazard ratio [HR] 1.094, 95% CI 1.068–1.121) and non-CKD populations (HR 1.027, 95% CI 1.001–1.055), with stronger effects among individuals with CKD than matched controls (relative HR 1.065, 95% CI 1.041–1.089). This pattern was consistent across all MACE components. $PM_{2.5}$ exposure was also associated with increased kidney-related hospitalization in both groups, without a significant interaction by CKD status. Notably, greater susceptibility among individuals with CKD was observed for urolithiasis (relative HR 1.151, 95% CI 1.089–1.218) and urinary tract infection (relative HR 1.067, 95% CI 1.036–1.099). Results were consistent in multipollutant models including NO_2 and ozone.
Conclusions : Long-term $PM_{2.5}$ exposure was associated with increased cardiovascular and kidney-related risks, with stronger effects among individuals with CKD, highlighting the importance of preventive strategies to reduce air pollution exposure, particularly among individuals with CKD.

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Figure. Exposure-response curves for the association between $PM_{2.5}$ and major health outcomes