Abstract

Environmental pollutant continue to pose a great threat to public health, leading to the development of chronic diseases. Susceptibility to the development of asthma may be influenced by either environmental exposure in the presence or absence of genetic predisposition. To examine the role of environmental exposure and genetic predisposition, a nonlinear mathematical model is formulated and analyzed to study the effect of genetic risk, environmental pollutant, and public health education/awareness on asthma development. Conditions for the existence of the unique positive steady-state, and permanence of the system were assessed. Using Lyapunov function analysis, the unique positive steady-state is locally and globally asymptotically stable. Results revealed that genetic risk, pollutant emission rate, effective exposure rate of the population to polluted environment, and recurrence rate contribute to asthma prevalence. However, sufficiently effective pollutant reduction strategies and improvement in compliance to public health education/awareness together with human-dependent environmental pollutant depletion lead to a marked reduction in disease prevalence.

Within the host, asthma pathogenesis involves activities of other Th cells, such as Th17 cells apart from the known Th1-Th2 cell interaction due to its severity. Pro-inflammatory cytokine, IL-23/IL-1β mainly produced by macrophages is considered essential for the differentiation of Th17 cells which mediate neutrophilic inflammation (a major inflammatory characteristic of severe asthma, and resistant to available therapy). Lipopolysaccharide (LPS) exposure variation induces eosinophilic phenotype mediated by Th2 cells, neutrophilic phenotype mediated by Th17 cells, or their coexistence in severe asthma. We developed a model for the regulation of Th2 cells, Th17 cells, and macrophages, incorporating IL-23/IL-1β cytokines as LPS exposure varies and predicted conditions for therapeutical interventions. The model exhibited two cases of steady states in the absence and presence of LPS with a transcritical forward bifurcation and mono-, bi-stability with hysteresis related to asthma severity, respectively. Bifurcation analysis predicted that the secretion rate of IL-23/IL-1β cytokines together with the leaving rate of macrophages are significant factors influencing neutrophilic inflammation, suggesting them as targets for an effective therapeutic protocol in controlling asthma severity moving the system further towards a more healthy outcome.

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