·论　著·

手足口病发病与气象因素的关联研究

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摘要：目的　探讨手足口病发病与气象因素的关联，为制定手足口病综合防控策略提供参考。**方法**　通过中国疾病预防控制信息系统收集上海市嘉定区2016—2023年手足口病发病资料，通过上海市气象局收集同期气象资料。采用分布滞后非线性模型（DLNM）分析日均气温、日均相对湿度、日均气压与手足口病日发病数的暴露-反应关系。**结果**　2016—2023年嘉定区报告手足口病21 555例，年均报告发病率为132.57/10万；其中男性12 762例，占59.21%；女性8 793例，占40.79%。发病主高峰为6—8月，次高峰为10—12月。DLNM分析结果显示，手足口病发病风险随日均气温升高先上升后下降，随滞后时间延长先下降后上升，日均气温为18.4～35.1 ℃时累积滞后风险较高，27.8 ℃时累积滞后效应最大（*RR*=5.522，95%*CI*：4.751~6.370）；手足口病发病风险随日均相对湿度升高先上升后下降，随滞后时间延长先下降后上升再下降，日均相对湿度为71.7%～90.8%时累积滞后风险较高，81.8%时累积滞后效应最大（*RR*=1.603，95%*CI*：1.321~1.995）；手足口病发病风险随日均气压升高而下降，日均气压高于1 015.80 hPa时，随滞后时间延长而下降，日均气压低于1 015.80 hPa时，随滞后时间延长而上升，986.80 hPa时累积滞后效应最大（*RR*=8.513，95%*CI*：1.401~36.625）。**结论**　嘉定区手足口病发病风险随气温、相对湿度升高先上升后下降，随气压升高而下降，且具有滞后性。

关键词：手足口病；气象因素；分布滞后非线性模型

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Association between incidence of hand-foot-mouth disease and meteorological factors

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Abstract: Objective　To examine the association between incidence of hand-foot-mouth disease (HFMD) and meteorological factors, so as to provide the basis for the prevention and control of HFMD. **Methods**　The number of HFMD cases in Jiading District, Shanghai Municipality from 2016 to 2023 were collected through the Chinese Disease Prevention and Control Information System, and meteorological data were obtained from the Shanghai Meteorological Bureau. The associations of daily average temperature, daily average relative humidity, and daily average atmospheric pressure with the daily number of HFMD cases were analyzed using a distributed lag non-linear model (DLNM). **Results**　A total of 21 555 HFMD cases were reported in Jiading District from 2016 to 2023, with an average annual incidence of 132.57/10^5. There were 12 762 male cases (59.21%) and 8 793 female cases (40.79%). The main peak of incidence occurred from June to August, and the secondary peak was from October to December. DLNM analysis showed that the incidence risk of HFMD first increased and then decreased with the increase of daily average temperature, and first decreased and then increased with the prolongation of the lag time. The cumulative lag risk was higher when the daily average temperature ranged from 18.4 to 35.1 ℃, and the maximum cumulative lag effect was observed at 27.8 ℃ (*RR*=5.522, 95%*CI*: 4.751-6.370). The incidence risk of HFMD first increased and then decreased with the increase of daily

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average relative humidity, and first decreased, then increased and then decreased again with the prolongation of the lag time. The cumulative lag risk was higher when the daily average relative humidity ranged from 71.7% and 90.8%, and the maximum cumulative lag effect was observed at 81.8% (*RR*=1.603, 95%*CI*: 1.321-1.995). The incidence risk of HFMD decreased with the increase of daily average atmospheric pressure, and decreased with the prolongation of the lag time when the daily average atmospheric pressure was greater than 1 015.80 hPa. When the daily average atmospheric pressure was less than 1 015.80 hPa, the incidence risk of HFMD increased with the prolongation of the lag time. The maximum cumulative lag effect was observed at 986.80 hPa (*RR*=8.513, 95%*CI*: 1.401-36.625). **Conclusion** The incidence risk of HFMD in Jiading District initially increases and then decreases with increasing temperature and relative humidity, while it decreases with increasing atmospheric pressure, and these effects exhibit a lagged response.

Keywords: hand-foot-mouth disease; meteorological factor; distributed lag non-linear model

手足口病是感染肠道病毒引起的常见传染病，发病率居我国丙类传染病前列[1]，5岁以下儿童高发[2]。手足口病的主要病原体为柯萨奇A组16型病毒和肠道病毒71型，潜伏期为2~10 d，表现为手掌、足底和臀部等部位出现斑疹或水疱，并伴有全身症状。该病具有明显的周期性和季节性，多在春夏季流行[3]，因地区差异可呈单峰、双峰和三峰等不同流行特征[4]。研究表明，气温、相对湿度等气象因素可通过改变病原体活性、宿主易感性和人类活动等影响手足口病流行[5-6]。本研究收集2016—2023年上海市嘉定区手足口病发病资料和同期气象资料，建立分布滞后非线性模型（distributed lag non-linear model，DLNM）分析气象因素对手足口病发病的影响及滞后效应，为制定手足口病综合防控策略提供参考。

1 资料与方法

1.1 资料来源

2016—2023年嘉定区手足口病病例资料来源于中国疾病预防控制信息系统；同期气象资料来源于上海市气象局日报数据；人口资料来源于上海市统计年鉴。

1.2 方法

收集临床诊断或实验室确诊为手足口病的病例资料，包括年龄、性别和人群分类等资料；收集日均气温、日均相对湿度和日均气压3种气象因素资料。手足口病日发病数接近准泊松分布，构建DLNM评估逐日时间维度下气象因素对手足口病发病的暴露-反应关系，根据手足口病最长潜伏期[4]，设定10 d最大滞后时间进行DLNM模型表达式分析。模型表达式如下。

$$\log\left[E\left(Y_t\right)\right]=\alpha+ns\left(\text{Time},10\times8\right)+cb\left(\text{Weather},\nu=3\right)+\log\left(caseslag10\right)+\text{DOW}+\text{Holiday}$$

式中：Y_t为第t天手足口病发病数；α为截距；*ns*（）为自然立方样条函数，Time为控制季节性和长期趋势的时间变量；*cb*（）表示交叉基函数，Weather为天气变量，ν表示自由度；log（）表示自然对数，*caseslag*为滞后时间；DOW为星期几效应；Holiday为节假日效应。日均气温、日均相对湿度和日均气压分别作为天气变量纳入模型，效应估计量采用相对危险度（relative risk，*RR*）值及其95%*CI*描述。

1.3 统计分析

采用Excel 2020软件整理数据，采用SPSS 21.0软件统计分析。趋势分析采用趋势χ^2检验，检验水准α=0.05。采用R 4.1.3软件的mgcv、Splines和dlnm程序包分析日均气温、日均相对湿度和日均气压对手足口病发病影响的非线性和滞后性。

2 结 果

2.1 基本情况

2016—2023年嘉定区报告手足口病21 555例，其中男性12 762例，占59.21%；女性8 793例，占40.79%。0~5岁组16 984例，占78.79%；>5岁组4 571例，占21.21%。散居儿童13 186例，占61.17%；幼托儿童5 972例，占27.71%；学生2 109例，占9.78%；其他288例，占1.34%。2016—2023年手足口病报告发病率分别为425.55/10万、139.40/10万、320.96/10万、144.63/10万、44.36/10万、76.35/10万、18.98/10万和155.56/10万，呈下降趋势（$\chi^2_{\text{趋势}}$=1 375.282，*P*<0.001），年均报告发病率为132.57/10万。手足口病发病呈明显季节性，主高峰为6—8月，次高峰为10—12月。

2.2 日均气温与手足口病发病的暴露-反应关系

日均气温对手足口病发病风险的影响呈现非线性特征和滞后效应。结果显示，当日均气温低于18.4 ℃时，*RR*值均<1，呈保护效应，且随滞后时间延长先减弱（滞后1~5 d）后增强；当日均气温高于18.4 ℃时，手足口病发病风险随日均气温升高先上升后下降，日均气温为33.5 ℃、滞后0 d时达单日风险峰值（*RR*=1.464，95%*CI*：1.060~2.023）。累积效

应分析结果显示，日均气温与手足口病发病风险呈倒“U”型关系，日均气温为18.4~35.1 ℃时手足口病发病累积滞后风险较高，27.8 ℃时累积滞后效应最大（*RR*=5.522，95%*CI*：4.751~6.370）。见图1。

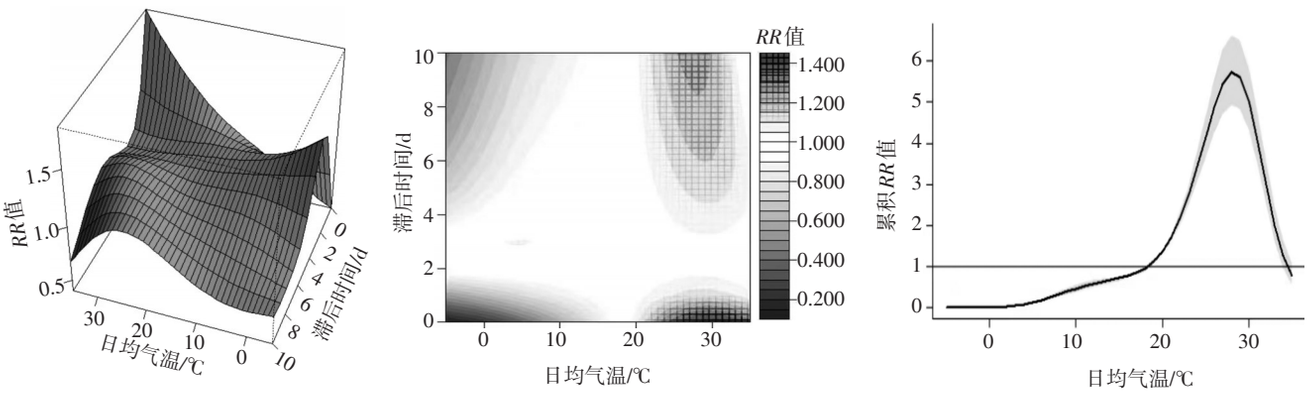

图1　日均气温与手足口病发病的暴露-反应关系

Figure 1　The exposure-response relationship between daily average temperature and the incidence of hand-foot-mouth disease

2.3　日均相对湿度与手足口病发病的暴露-反应关系

日均相对湿度对手足口病发病风险的影响呈现复杂的非线性特征和多阶段滞后效应，当日均相对湿度低于71.7%时，*RR*值均＜1，呈保护效应，且随滞后时间延长呈先减弱后增强再减弱的动态波动；当日均相对湿度高于71.7%时，手足口病发病风险随日均相对湿度升高先上升后下降，日均相对湿度为87.0%、滞后0 d时达单日风险峰值（*RR*=1.059，95%*CI*：0.976~1.148）。累积效应分析结果显示，日均相对湿度与手足口病发病风险呈倒“U”型关系，日均相对湿度为71.7%~90.8%时手足口病发病累积滞后风险较高，81.8%时累积滞后效应最大（*RR*=1.603，95%*CI*：1.321~1.995）。见图2。

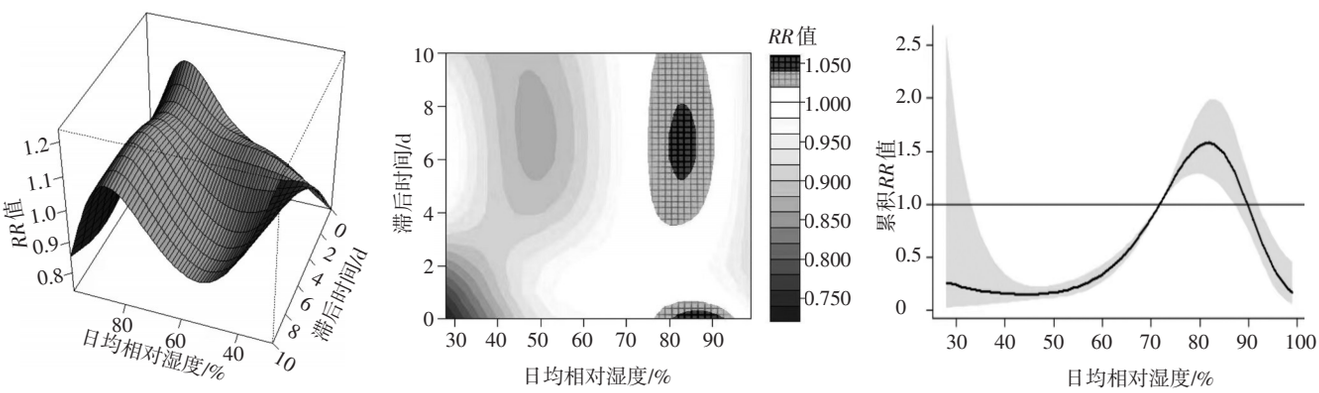

图2　日均相对湿度与手足口病发病的暴露-反应关系

Figure 2　The exposure-response relationship between daily average relative humidity and the incidence of hand-foot-mouth disease

2.4　日均气压与手足口病发病的暴露-反应关系

日均气压对手足口病发病风险的影响呈现非线性特征和滞后效应。当日均气压高于1 015.8 hPa时，滞后0~3 d手足口病发病风险较高，日均气压为1 042.1 hPa、滞后0 d时达单日风险峰值（*RR*=2.513，95%*CI*：1.098~5.748），但随滞后时间延长手足口病发病风险下降；当日均气压低于1 015.8 hPa时，随滞后时间延长手足口病发病风险上升，滞后4~10 d时手足口病发病风险较高。累积效应分析结果显示，日均气压与手足口病发病风险近似呈负线性关系，日均气压为986.8 hPa时累积滞后效应最大（*RR*=8.513，95%*CI*：1.401~36.625）。见图3。

3　讨　论

2016—2023年嘉定区共报告手足口病病例21 555例，男女比为1.45∶1，以0~5岁、散居儿童为主，与四川省泸州市的流行特征[7]基本一致。手足口病发病有明显的季节性，6—8月为主高峰，10—12月为次高峰，与浙江省嘉兴市吴兴区[8]和宁波市海曙区[9]研究结果基本一致。本研究构建DLNM分析手

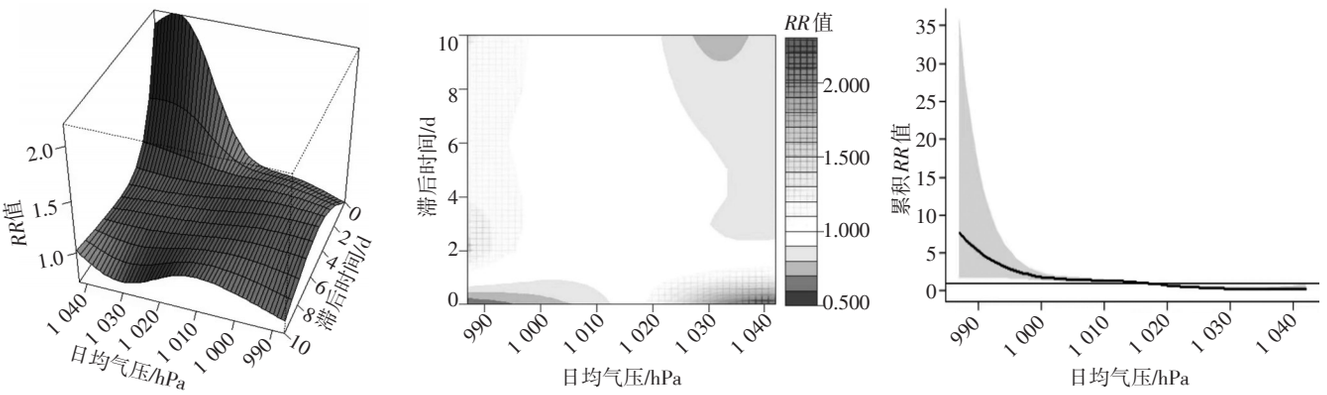

图3 日均气压与手足口病发病的暴露-反应关系

Figure 3 The exposure-response relationship between daily average atmospheric pressure and the incidence of hand-foot-mouth disease

足口病日发病数与日均气温、日均相对湿度和日均气压的关联，结果显示，3种气象因素对手足口病发病风险的影响均呈现非线性特征和滞后效应。

日均气温为33.5 ℃、滞后0 d时，手足口病发病风险最高，与江苏省扬州市手足口病发病风险在气温为-7.4 ℃且滞后0 d时达最高值的结果[10]不一致。可能因为手足口病发病具有空间异质性，人口密度等社会环境因素也会影响手足口病发病与气温的关联[11]。日均气温与手足口病发病风险呈倒“U”型，即在温度较为适宜时发病风险较高，可能与低温或高温抑制肠道病毒生长、影响病原体活力有关[10]。随着滞后时间延长，手足口病发病风险呈现先下降后上升趋势，在27.8 ℃时累积滞后效应最大，与北京市的25.5 ℃[12]接近。

日均相对湿度低于71.7%时，手足口病发病风险降低，表现为保护作用，与既往研究结果[13]类似。日均相对湿度为87.0%、滞后0 d时手足口病发病风险最高，日均相对湿度为81.8%时累积滞后效应最大，空气中水分含量较高有利于肠道病毒的存活与传播，可增加手足口病发病风险[14]。上海市梅雨季节降雨较频繁，容易形成高湿度环境，与6—8月手足口病高发的季节性特征相符。

日均气压在1 042.1 hPa、滞后0 d时，手足口病发病风险最高，提示高气压对手足口病发病的影响是即时的。气压小于1 015.8 hPa时，手足口病发病风险随着滞后时间延长而上升，日均气压为986.8 hPa时累积滞后效应最大，可能因为低气压容易使人出现呼吸急促、心率加快等症状，引起身体不适和免疫力下降，增加感染手足口病风险[15]。

本研究存在一定局限性，仅分析了手足口病与气温、相对湿度和气压的关联，未纳入其他环境因素、行为因素和生物因素等。今后应拓展多维度变量完善研究模型，建立并完善手足口病综合防控策略和联防联控机制。

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