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Determination of priority areas for dengue control actions

ABSTRACT

OBJECTIVE: To identify areas at risk of dengue transmission by means of cluster analysis.

METHODS: A cluster analysis in which the primary analysis units were the 48 districts of the municipality of Niterói, Southeastern Brazil, was conducted. The districts were grouped into six strata according to sociodemographic conditions, using the k-means cluster analysis method. After defining the strata, the incidence of dengue was calculated for each stratum in relation to four different periods: 1998 – 2000; 2001; 2002; 2003 – 2006.

RESULTS: The analysis on the incidence showed that the rates for the last three study periods were greatest in the stratum 2.1, which had the worst sanitation infrastructure conditions and high population increases, and in stratum 3.1, which had the highest percentage of shantytowns. Stratum 1.2 presented the lowest incidence and the best sanitation and income indicators, along with small increases in population and a low proportion of shantytowns. The incidence rates in 2001 and 2002 were high in most strata except for stratum 1.2, which had the districts with the least heterogeneity in relation to the indicators used. In 2001, the strata presented high rates of incidence when group immunity had supposedly become established for serotype I, thus expressing the transmission strength of this agent.

CONCLUSIONS: The cluster analysis technique made it possible to recognize priority areas. It indicated areas where the dengue control and surveillance actions needed to be improved, along with structural improvements that influenced the living conditions and health of the municipality's population.

DESCRIPTORS: Dengue, epidemiology. Cluster Analysis. Risk Factors.

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INTRODUCTION

A variety of methodologies have been used to characterize the epidemiology of endemic diseases, with the aim of formulating control strategies. For prevention and control measures to be effective, it is very important that the methodology that best highlights the environmental and social processes influencing disease transmission patterns should be used. Thus, stratification of the space according to socioenvironmental indicators, with the addition of information relating to the level of endemicity of the area, is an important instrument for supporting the planning of control actions.[4,7]

The distribution of the risk of exposure to the dengue virus, in relation to different social and economic situations, is still an issue presenting contradictions. It has been correlated both with areas in which populations live under precarious conditions,[6] and with populations living in more favorable situations.[13,14]

The demographic and socioeconomic characteristics of territorial units need to be known in order to analyze different health situations, along with the characteristics of their population groups.[a] All of these elements characterize territories and form the basis for the territorial stratification that is applied for health surveillance.[3] This proposal, which is contained within the new model for health surveillance, is justified by the worsening of the social inequalities that are associated with spatial segregation. Such segregation restricts these populations' access to better living conditions.[9]

The conditions in the city of Niterói, state of Rio de Janeiro, Southeastern Brazil, have favored transmission of the dengue virus. Simultaneous circulation of serotypes 1 and 2 caused a major epidemic in 1990-1991. Two other large epidemics have occurred in this municipality: one in 2001 with the reintroduction of serotype 1 and the other in 2002 with the introduction of serotype 3.[b]

A large proportion of ecological studies within the field of epidemiology have used political-administrative areas representing slices of geographical space, in order to detect transmission patterns.[2] However, these areas do not always represent the reality involved in the epidemiological dynamics of the disease.

In this light, territorial stratification makes it possible to determine the spatial size of events by means of aggregation according to the homogeneity of the characteristics, with disaggregation of territories presenting heterogeneity.[3] For this, studies have used cluster analysis to seek spatial patterns of events and characterize homogenous areas.[3,6]

Analysis on the role of human populations and infestations by *Aedes aegypti* in each territory, taking into consideration the socioeconomic conditions and the environment within which they interact, may contribute towards identifying the role of each agent in maintaining the circulation of the virus. This may add elements to the debate on prevention strategies.[12] Therefore, the aim of the present study was to characterize areas at risk of dengue transmission by means of cluster analysis according to socioeconomic and demographic indicators.

METHODS

This study was developed in the municipality of Niterói, in the metropolitan region of the state of Rio de Janeiro. Niterói is considered to be a medium-sized municipality, covering an area of 131.5 km² and with a demographic density of 3487.43 inhabitants/km². The population was estimated by *Instituto Brasileiro de Geografia e Estatística*[c] (IBGE - Brazilian Institute for Geography and Statistics) to be 475,000 inhabitants in 2007. Around 78% of households were connected to the general water supply network; around 70% were connected to the sewage system; and 81% were served by garbage collection. The main economic activity was in the tertiary serviced provision sector.[d] The municipality is in third place in the national ranking of the human development index (HDI) and in first place in the state ranking.

An ecological study was conducted on clustered data, taking the 48 districts of the municipality as the primary units. Subsequently, these districts were grouped according to social and demographic conditions, into six areas (strata).

The non-hierarchical k-mean method was used. The aim of this method was to classify the units into a certain number of clusters that were defined previously. The technique starts from these k-clusters, and moves the units between the clusters in order to maximize the variability between the clusters, while minimizing it within the clusters. Through this, results of greater significance can be obtained in analysis of variance.[1]

A correlation matrix on the 13 indicators constructed based on the variables in the demographic census of 2000[e] was generated. Two variables that presented strong correlations (Pearson correlation coefficient greater than 0.9) with other variables were removed from the analysis. These were the proportion of heads of permanent private households with up to three years of schooling, which presented a strong correlation with the variable of the proportion of heads of permanent private households with up to two minimum monthly salaries; and the variable of demographic density, which presented a strong correlation with the population density in terms of the internal area.

The stratification was based on analysis of 11 indicators: proportion of permanent private households connected to the water supply network (WATER); proportion of permanent private households with garbage collection carried out by the cleansing services (GARBAGE); proportion of permanent private households connected to the sewage system (SEWAGE); proportion of heads of permanent private households with income of up to two minimum monthly salaries (UPTO2SAL);

[a] Organización Panamericana de la Salud. Grupo Interdisciplinario de Estudios en Salud; Ministerio de Salud. Sistema Nacional de Vigilancia de Situación de Salud Según Condiciones de Vida. La Habana; 1994.
[b] Silveira NAPR. Distribuição territorial de dengue no Município de Niterói, 1996 a 2003. [Master's dissertation]. Rio de Janeiro: Escola Nacional de Saúde Pública da Fiocruz; 2005.
[c] Instituto Brasileiro de Geografia e Estatística. Censo brasileiro 2000: resultados preliminares. Rio de Janeiro; 2000.
[d] Prefeitura Municipal de Niterói. Secretaria Municipal de Desenvolvimento, Ciência e Tecnologia. Perfil de uma cidade. Rio de Janeiro; 2000.
[e] Instituto Brasileiro de Geografia e Estatística. Censo brasileiro 2000: resultados preliminares. Rio de Janeiro; 2000.

proportion of permanent private households of apartment type (APART); population density in terms of internal area per km² (2001) (DENSINTERN); proportion of households in shantytowns (SHANTY); proportion of permanent private households with more than eight residents (8+RES); proportion of residents over 70 years of age (70+YEARS); percentage of internal area greater than the level of 40 m² (2001) (INTERN+40), obtained through satellite image classification for the years 1986 and 2001; and population increase (INCR). All the variables were normalized.

The variables were chosen with the aim of covering factors that have been described as social macrodeterminants of dengue.[a] The proportion of permanent private households with more than eight residents and the proportion of residents over 70 years of age were used as indicators of living conditions. The percentage of the internal area greater than the level of 40 m² and the population density in terms of internal area were used by Silveira[b] (2005) as indicators of altitude and urbanization, respectively.

The stratification was done in two stages. In the first stage, cluster analyses with three strata were performed, in which all the variables contributed importantly to the general model. In the second stage, analysis using two strata was performed for each stratum obtained in the first stage, thus totaling a set of six strata. The reason for performing the second stage of cluster analysis was that differences were observed within important variables in each stratum of the first stage (Table 1). In addition, some districts belonging to the same stratum still appeared to be very heterogenous in relation to the variables analyzed.

The strata were chosen based on tests and retests, and the final six strata were the ones that best represented the event under evaluation. After defining the strata, the dengue incidence rate was calculated per stratum for four periods: I- 1998 to 2000, i.e. the endemic period after the introduction of serotype 2 and before the epidemic of serotype 1; II- 2001, i.e. the epidemic period when serotype 1 was reintroduced; III- 2002, i.e. the epidemic period when serotype 3 was introduced; and IV- 2003 to 2006, i.e. the endemic period with circulation of serotype 3 after the epidemic of its introduction. The population data were obtained from the demographic census of 2000 and from population estimates for the years between censuses.[c] To obtain the number of dengue cases, duplicate records were excluded and only cases with clinical epidemiological confirmation were considered. These data were obtained from the National Notifiable Diseases System (*Sistema Nacional de Agravos de Notificação* - SINAN) at the Municipal Health Department of Niterói. Analysis of variance was performed to investigate the statistical significance of any differences in incidence found between the strata and analysis periods.

The Statistica 6.0 and MapInfo 6.0 software were used in the analysis.

This study was approved by the Research Ethics Committee of the *Escola Nacional de Saúde Pública* (ENSP).

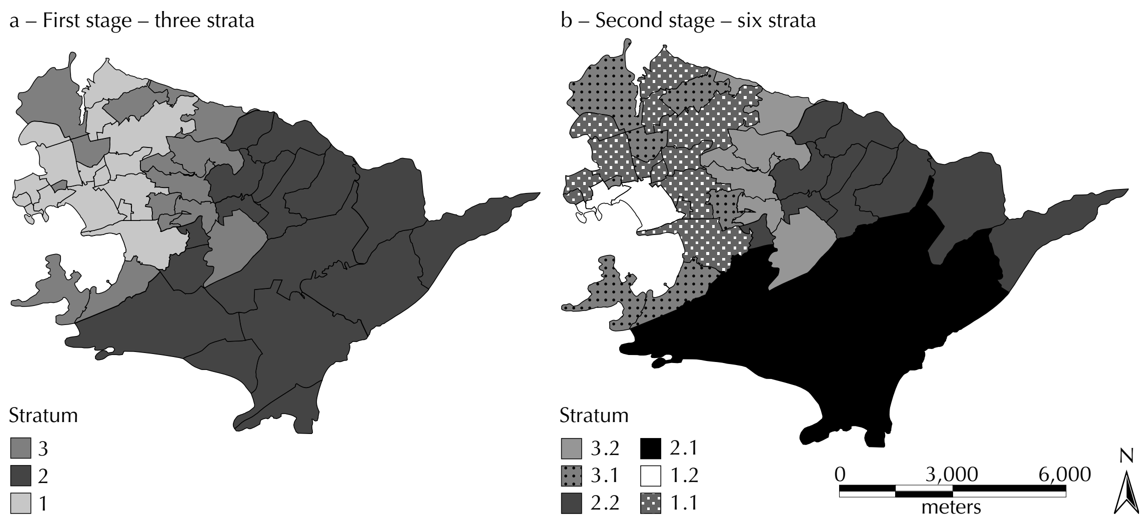
RESULTS

The main characteristics of the three strata of districts according to social and demographic conditions that were generated in the first stage showed that stratum 1 was formed by districts with low population growth. Its residents had the best income levels, greatest longevity, best conditions of sanitation service infrastructure, highest proportion of housing of apartment type (located in areas of high population density) and smallest proportion of substandard clusters. Stratum 2 was characterized by districts with high population growth in which the residents had intermediate income levels and the lowest conditions of sanitation service infrastructure. The housing ranged in type from simple houses to the most sophisticated housing in condominiums with low population density, and with a small proportion of shantytowns. Stratum 3 was composed of districts with low population growth in which the residents had low income, lower longevity, intermediate conditions of sanitation service infrastructure and the lowest percentage garbage collection by the cleansing services. The housing consisted of simple houses located in areas of medium population density and with the presence of substandard housing (Figure 1a and Table 2).

The highest coefficients of dengue incidence for the four periods were found in stratum 2, and these were respectively 1.34, 2.27, 1.24 and 1.72 times greater than the values calculated for the whole municipality of Niterói (Table 3).

Among the main characteristics of the six strata of districts according to social and demographic conditions that were generated in the second stage, stratum 1.2 was composed of districts presenting indicators of income, proportion of homes of apartment type, proportion of garbage collection and population density in terms of internal area that were greater than those of

[a] Organização Panamericana de Saúde. Diretrizes relativas à prevenção e ao controle da dengue e da dengue hemorrágica nas Américas: relatório da Reunião sobre Diretrizes para a Dengue. Washington;1991.
[b] Silveira NAPR. Distribuição territorial de dengue no Município de Niterói, 1996 a 2003. [Master's dissertation]. Rio de Janeiro: Escola Nacional de Saúde Pública da Fiocruz; 2005.
[c] Instituto Brasileiro de Geografia e Estatística. Censo brasileiro 2000: resultados preliminares. Rio de Janeiro; 2000.



Source: Brazilian Institute for Geography and Statistics. Brazilian census 2000: preliminary results. Rio de Janeiro; 2000

Figure 1. Consolidated strata of districts according to indicators of social and demographic conditions. Municipality of Niterói, Southeastern Brazil, 1998-2006.

stratum 1.1; stratum 2.1 was composed of districts with population growth and income that were greater than those of stratum 2.2, along with lower infrastructure levels of general water supply and lower proportions of internal area greater than the level of 40 m²; stratum 3.1 was composed of districts with indicators of the proportion of shantytowns and sanitary service infrastructure conditions that were greater than those of stratum 3.2, along with a lower proportion of internal area greater than the level of 40 m² (Figure 1b and Table 2).

Comparing the coefficients of dengue incidence calculated in the first stage (three strata) with those calculated in the second stage (six strata), it was observed that the rates in the second stage were more differentiated and presented greater variation between strata (higher coefficient of variation). The results from the analysis of variance showed that the differences in incidence between the periods ($p = 0.00$) and between the strata ($p = 0.06$) were significant ($p < 0.10$). Analysis on the incidence according to the indicators used showed that

Table 1. Important intra-stratum variables. Municipality of Niterói, Southeastern Brazil, 2000.

Analysis of variance			
Stratum	Important variables	F test	p
Stratum 1	DENSINTERN	10.672	0.00
	GARBAGE	4.604	0.04
	APART	16.259	0.00
	UPTO2SAL	16.335	0.00
	8+RES	12.975	0.00
Stratum 2	INTERN+40	93.784	0.00
	WATER	7.211	0.01
	DENSINTERN	4.019	0.06
	UPTO2SAL	4.389	0.05
Stratum 3	INTERN+40	29.256	0.00
	SEWAGE	20.292	0.00
	APART	4.374	0.05

Source: Brazilian Institute for Geography and Statistics. Brazilian census 2000: preliminary results. Rio de Janeiro; 2000.
WATER: proportion of private households connected to the water supply network; GARBAGE: proportion of private households with garbage collection; SEWAGE: proportion of private households connected to the sewage system; UPTO2SAL: proportion of heads of private households with income of up to two minimum monthly salaries; APART: proportion of households of apartment type; DENSINTERN: population density in terms of internal area per km²; SHANTY: proportion of households in shantytowns; 8+RES: proportion of private households with more than eight residents; 70+YEARS: proportion of residents over 70 years of age; INTERN+40: percentage of internal area greater than 40 m²; INCR: population increase.

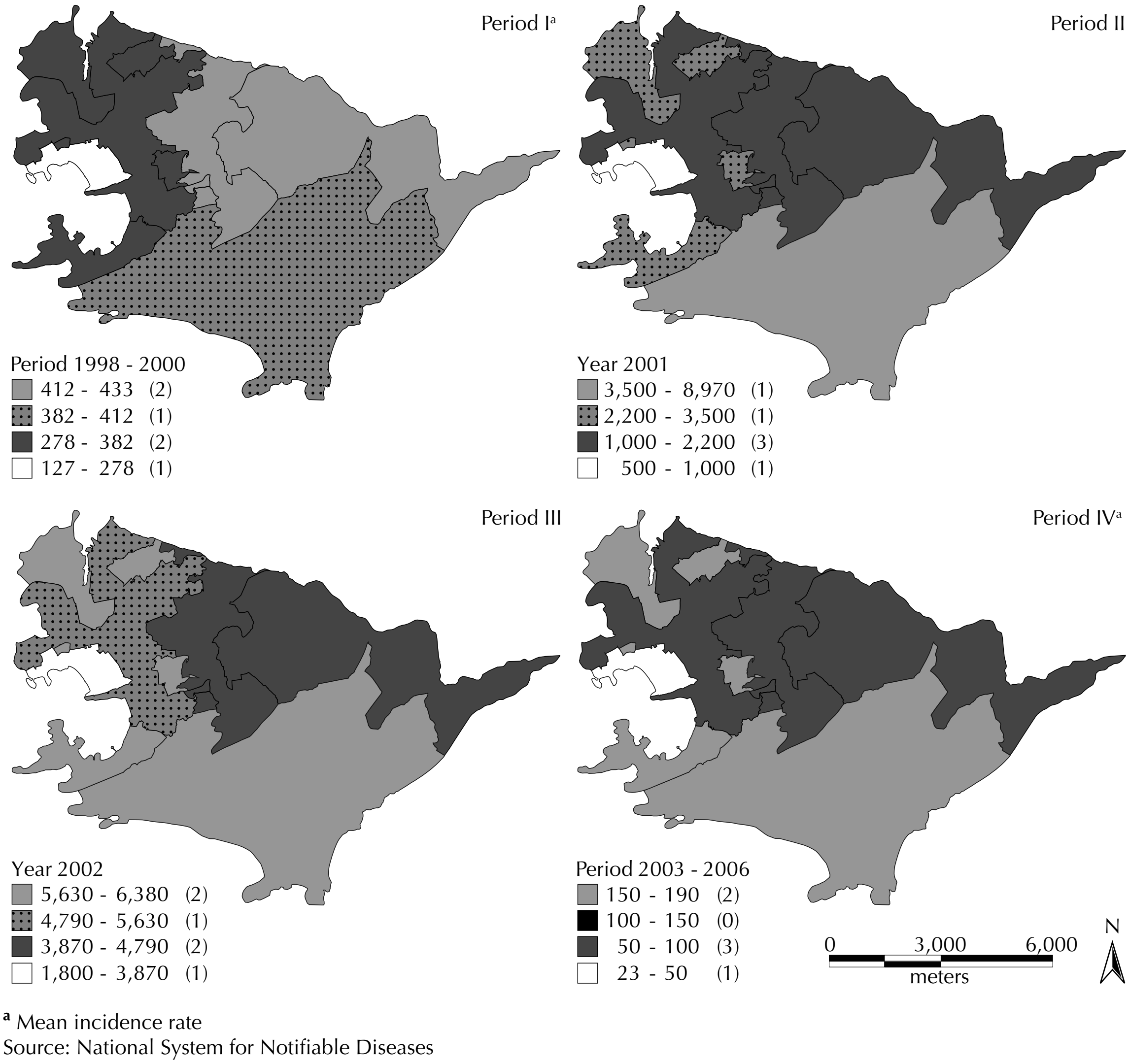


Figure 2. Dengue incidence rate (100,000 inhabitants) for each analysis period. Municipality of Niterói, Southeastern Brazil,,2000.

the rates for the last three study periods were greater in the strata with the lowest conditions of sanitary service infrastructure and high population growth (stratum 2.1) and high percentage of shantytowns (stratum 3.1). Furthermore, the greater rate of dengue incidence found in stratum 2 in the first stage was due mainly to this expanding area of the urban periphery (stratum 2.1). Throughout the study period, stratum 1.2 presented the lowest incidence rate and the best sanitation and income indicators, along with small population increases and the smallest proportion of shantytowns. Stratum 2.2 presented the lowest risk of dengue transmission during the epidemic years. The incidence rates in 2002 were high in most strata, except for stratum 1.2. In addition, there was a substantial increase in incidence in 2002 in most strata, except in 2.1 (Figure 2 and Table 3).

DISCUSSION

In the present study, the cluster level used was the stratum, and the most homogenous of these was stratum 1.2 (which was formed by only three districts). All the other strata included districts with a certain degree of heterogeneity of socioeconomic and demographic characteristics.

According to Machado et al[8] (2007), dengue cases occur mainly in heterogenous areas, defined as specific geographical spaces in which a diversity of socioeconomic strata coexist in the same region. Such areas would thus favor diffusion and maintenance of dengue. Sabroza et al[10] (1992) stated that the way in which spaces are occupied by populations within different socioeconomic strata may make them vulnerable and create conditions that favor the production and reproduction of diseases.

Table 2. Intra-stratum indicators of social and demographic conditions. Municipality of Niterói, Southeastern Brazil, 2000.

STRATUM	WATER	SEWAGE	GARBAGE	APART	UPTO2SAL	70+ YEARS	8+ RES	INCR	SHANTY	INTERN +40	DENS INTERN
1	98.10	94.57	91.30	64.64	12.90	8.47	0.73	0.46	5.81	15.42	16941.40
1.1	97.32	91.70	87.27	48.86	18.01	7.29	1.01	0.52	6.55	16.92	13908.92
1.2	99.39	99.28	97.92	90.57	4.50	10.56	0.26	0.17	2.60	8.89	30082.13
2	21.76	15.49	81.89	1.50	23.50	3.84	1.46	5.78	4.41	54.07	6424.35
2.1	3.73	8.31	85.74	1.81	18.03	3.88	1.48	7.90	6.31	6.14	4571.61
2.2	49.42	26.52	75.97	1.02	31.91	3.77	1.45	4.29	3.08	87.63	7721.26
3	71.36	61.89	54.97	5.15	39.96	4.02	1.96	-1.10	27.22	56.09	13459.14
3.1	88.98	79.99	62.79	7.98	37.02	4.51	1.99	-1.57	38.25	26.95	14827.06
3.2	50.43	40.39	45.68	1.79	43.46	3.44	1.93	-0.55	14.62	89.38	11895.80

Source: Brazilian Institute for Geography and Statistics. Brazilian census 2000: preliminary results. Rio de Janeiro; 2000.
WATER: proportion of private households connected to the water supply network; GARBAGE: proportion of private households with garbage collection; SEWAGE: proportion of private households connected to the sewage system; UPTO2SAL: proportion of heads of private households with income of up to two minimum monthly salaries; APART: proportion of households of apartment type; DENSINTERN: population density in terms of internal area per km^2; SHANTY: proportion of households in shantytowns; 8+RES: proportion of private households with more than eight residents; 70+YEARS: proportion of residents over 70 years of age; INTERN+40: percentage of internal area greater than 40 m^2; INCR: population increase.

Table 3. Dengue cases and incidence rate (100,000 inhabitants) per stratum and period. Municipality of Niterói, Southeastern Brazil, 2000.

Stratum	1998 – 2000[a]		2001		2002		2003 – 2006[a]	
	Cases	Incidence	Cases	Incidence	Cases	Incidence	Cases	Incidence
1	1866	236.63	4278	1637.13	9668	3710.09	448	43.25
1.1	1508	296.74	3368	2015.10	7964	4795.76	359	54.88
1.2	358	127.66	910	966.31	1704	1802.73	89	23.32
2	1040	394.18	5994	6165.11	5553	5420.27	667	141.66
2.1	602	382.15	5329	8967.97	4040	6376.67	568	189.29
2.2	438	412.00	665	1759.17	1513	3870.28	99	57.97
3	1109	349.04	2281	2188.85	5105	4933.82	464	113.81
3.1	477	278.06	1280	2281.27	3135	5637.18	350	160.60
3.2	632	432.33	1001	2081.05	1970	4116.47	114	60.07
Niterói	4015	293.03	12553	2712,72	20326	4357.08	1579	82.49

[a] Mean incidence rate
Source: National System for Notifiable Diseases

The analysis on the incidence rate according to the living condition strata showed that the rates for the last three periods studied were greatest in stratum 2.1 (with the worst conditions of sanitation service infrastructure and high population growth) and in stratum 3.1 (with the highest percentage of shantytowns). Thus, strata 2.1 and 3.1 were highlighted as priority areas for dengue control actions. On the other hand, the districts in stratum 1.2 presented the lowest heterogeneity in relation to the indicators used in this study, the lowest incidence rate and the best sanitation and income indicators, as well as low population growth and a low proportion of shantytowns, thus corroborating Machado et al[8] (2007).

The epidemic of serotype 1 in 2001 was concentrated in stratum 2.1. This is an area of intense real estate speculation, with great population growth, increasing land value and homes for the upper middle class population, with income and schooling levels above the average for the municipality.[a] The high incidence rates observed in different strata in 2001 was an unexpected finding, given that group immunity to serotype 1 had supposedly been established during the preceding period. It is likely that both the socioenvironmental characteristics of the municipality and the still-low degree of immunity among the population were relevant for the epidemic behavior encountered during this year.

For better understanding of how the degree of immunity among the population modulates transmission in urban areas, serological studies specific for each of the types

[a] Prefeitura Municipal de Niterói. Secretaria Municipal de Desenvolvimento, Ciência e Tecnologia. Perfil de uma cidade. Rio de Janeiro; 2000.

of dengue virus are necessary. However, no such studies have yet been conducted in this region.

During the epidemic of serotype 3 in 2002, one important factor that may have favored the explosion in numbers of cases was the population's susceptibility to this type of recently introduced virus, given that individual or collective immunity is not permanent. The incidence levels increase if a new virus is introduced or if there is a decline in collective immunity to the circulating virus.[11] This would explain the magnitude and diffusion of the epidemic in Niterói, with incidence much greater than previously and distribution between the strata that was more homogenous: with predominance in stratum 2.1, a high coefficient in stratum 3.1 and slightly lower coefficients in strata 1.1 and 3.2. Stratum 2.2 was less affected, despite its characteristics favoring transmission, and this suggests that its vulnerability was lower, possibly explained by relative protection due to the persistence of significant plant coverage[a] and few inhabitants in terms of internal area. Such characteristics are unfavorable for increases in population density among vectors that have adapted to urban environments, such as *Aedes aegypti.*

The association between risk of dengue transmission and the socioeconomic and environmental conditions is a question requiring deeper analysis, while taking into consideration the realities in each municipality. It is important to analyze the spatial relationships between dengue transmission and other variables, such as the population's degree of immunity, the effectiveness of the control measures, the degree of infestation by the vector and the population's habits and behavioral patterns, among others.

The different associations found in different studies on dengue occurrence and socioeconomic and environmental conditions may be related to the types of clusters used (census tracts, districts, zones and/or municipalities) and to the type of data used (primary or secondary data). Regarding the type of cluster used, the different results obtained using spatial slices are called problems of the modifiable area unit. By clustering the epidemiological and demographic data into larger units, the effect of rate instability is reduced. However, this clustering may falsify the information, through construction of large means that cover up internal differences.[5] Regarding the secondary data obtained from official notification systems, these systems generally record cases for which medical attendance within the public system was sought. The public system is used more by the low-income population, and thus the data from these systems do not include a large proportion of the cases that occur in areas of the city with better living conditions. This may lead to distortions in the knowledge of dengue virus circulation.[12]

Transformation of geographical space and social dynamics appear to be fundamental factors in dengue production in Niterói. Historical-social processes and transformation of geographical space, among other factors, determine local living conditions. Unplanned urban development, high population growth, intermittent water supplies, irregular garbage collection, intense movement of people and the lack of effectiveness of the control measures are factors that favor maintenance of endemic disease and occurrences of important epidemics in Niterói.

The spatial units usually used in epidemiological studies, such as districts, municipalities and states, result from the form of data aggregation in the information systems. However, neither the environmental nor the social processes that promote or restrict situations of risk to health are limited to these political-administrative boundaries. With regard to ecosystem approaches used in public health studies, there is still a need to develop methodologies that are capable of identifying and acting on social and environmental determinants. By choosing spatial units for data clustering that best highlight the social and environmental processes, processes that occur at scales differing from political-administrative divisions can be better understood.[2]

Most ecological studies within epidemiology use political-administrative divisions as the unit for analysis and investigation of disease transmission patterns *a posteriori*. On the other hand, in the present study, it was sought to identify areas of greater transmission of dengue based on clustering in areas constructed *a priori*, through environmental, socioeconomic and demographic criteria.

According to Silveira[b] (2005), instability in indicators for disease frequency in territorial units with small populations (census tracts, urban districts, rural localities and even municipalities with fewer than 10,000 inhabitants) has brought problems for statistical analyses on data consolidated at these levels of clustering, thereby leading to the use of Bayesian statistics. Another alternative, which was used in the present study, was to consolidate data into discontinuous strata that are commonly defined by socioeconomic and/or environmental indicators.

Thus, the methodology used was shown to be useful for surveillance and for epidemiological investigations. Identification of disease occurrence patterns, according to the distribution of factors that favor the appearance, distribution and behavior of diseases affecting

[a] Prefeitura Municipal de Niterói. Secretaria Municipal de Desenvolvimento, Ciência e Tecnologia. Perfil de uma cidade. Rio de Janeiro; 2000.
[b] Silveira NAPR. Distribuição territorial de dengue no Município de Niterói, 1996 a 2003. [Master's dissertation]. Rio de Janeiro: Escola Nacional de Saúde Pública da Fiocruz; 2005.

the population's health, facilitates the planning and development of interventions of greater effectiveness. However, environmental variables and other variables portraying the population's immunological profile should also be used, along with complementary methodological procedures (construction of summarized risk indicators and geoprocessing methodology, among others), thereby enabling deeper analysis.

The present study has certain limitations. Socioeconomic information was only available for the years of the demographic census and the population estimates were calculated by taking the growth to be geometric, at a constant rate equal to what was observed for the period 1996-2000. Furthermore, the intense mobility of the population, for work, study or leisure purposes, made it difficult to analyze the areas with greatest dengue transmission, since individuals might become infected in neighboring or distant districts. One possibility for dealing with this problem would be to analyze cases occurring among children up to the age of ten years: it is accepted that the level of mobility among this age group is lower.

In addition, the results from epidemiological studies using secondary data from disease notifications may be greatly influenced by under or overestimation of cases caused by diagnostic errors, problems of access to healthcare services and the frequency of asymptomatic infections.[12]

Through recognizing priority areas in Niterói, the present study has indicated where improvements in surveillance and control actions should be directed, along with structural improvements that would influence the living conditions and health of the municipality's population.

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