Mapping Childhood Obesity and Overweight Patterns in Attica, Greece, A GIS-Based Approach

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Abstract
Childhood obesity is a major public health issue worldwide. Spatial investigational approaches focus on analyzing spatial patterns of obesity and investigating the association between childhood obesity and socioeconomic and environmental conditions. This study analyses the spatial distribution and potential clusters of childhood obesity in Attica prefecture (broader Athens metropolitan area), using a GIS-based approach. Our findings highlight high rates of obesity across study area, as well as spatial clustering of childhood obesity.

1. Background

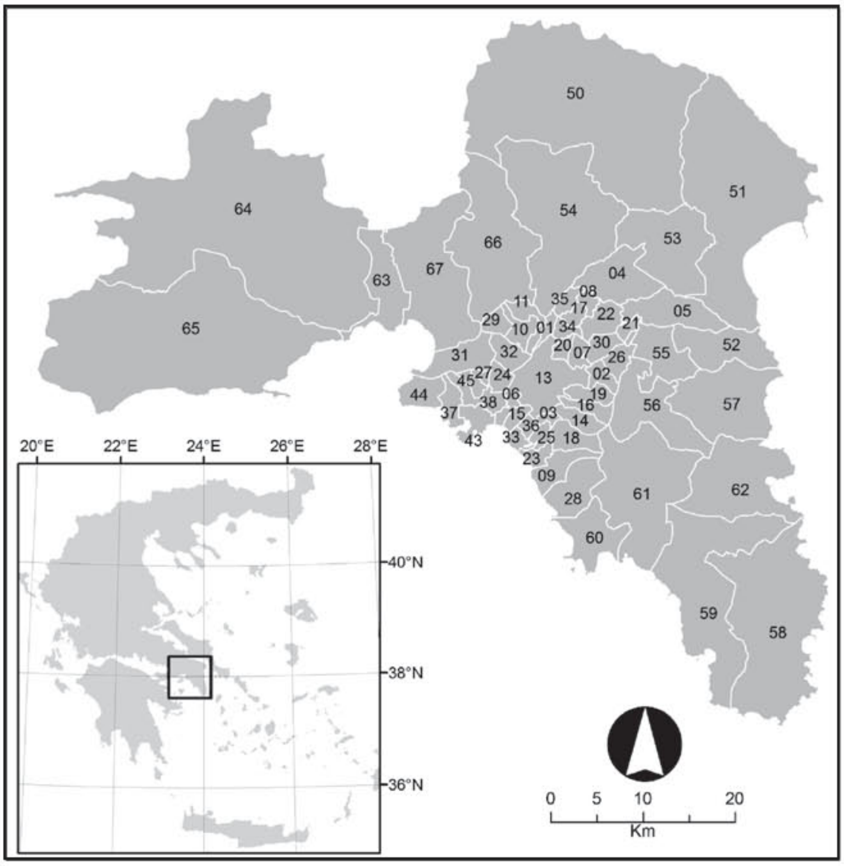
In the last decades, the world-wide prevalence of obesity has reached dangerously high levels. Predictive models suggest that the ratio obese-to-thin children will continue to rise in the future (Kosti and Panagiotakos, 2006). If this trend retain in the near future, the number of overweight children in the European Union is expected to rise by 1.3 million per year, with more than 300.000 of them becoming obese each year (Wang and Lobstein, 2006). Thus, childhood obesity has been recognized as an important public health issue in most developed and developing countries (James, 2008, Martorell et al., 2000). To the best of our knowledge, only few studies (Krassas et al., 2001 and Georgiadis and Nassis, 2007) have estimated the prevalence of childhood obesity in Greece; most of them have drawn conclusions from selected geographic areas (Krassas et al., 2001 and Tokmakidis et al., 2006). Moreover, even in the international literature, the geospatial study of childhood obesity/overweight (Pouliou and Elliott, 2009, Rosenberger et al., 2005, Michimi and Wimberly 2010 and Pearce and Witten, 2010) only recently emerges. Therefore, the aim of this study was to assess the spatial distribution as well as the spatial clustering of childhood obesity/overweight (CObOW), in Attica prefecture, Greece. For this purpose, geospatial research for the "obesity/overweight epidemic" was implemented with the use of Geographic Information Systems (GIS) technology in a spatial analysis research context. Visualizations of spatial distributions and estimations of spatial patterns - implemented within GIS context - can be useful tools to help local authorities and decision makers conceptualize health problems and their spatial dimension across broad geographical areas. Thus, many researchers notice the role of GIS in health research (among others Croner et al., 1996, Rushton, 2003 and Bhowmick et al., 2007). Geospatial research in health science is divided into the following general categories: a) Thematic mapping of the spatial distribution of diseases (among others Rushton and Lolonis, 1996 and Langford et al., 1999), b) Spatial pattern detection methods as Openshaw's Geographical Analysis Machine (GAM - Openshaw, 1995), Kulldorff's Spatial Scan Statistic (Kulldorff, 1997 and 2001), geographically weighted regression (Brunsdon et al., 1998 and Fotheringham et al., 2002) and Exploratory Spatial Data Analysis (Anselin, 1995 and Jacquez et al., 2005) and c) Investigation of the relationships between health problems and various socioeconomic and environmental variables (e.g., Chaikaew et al, 2009, Lim et al., 2010 and Cao et al., 2010). Here, we consider the spatial distribution and spatial patterns of childhood obesity focusing our analysis on Attica prefecture, Greece, at a regional scale. This analysis addresses the following questions: a) what is the spatial distribution of CObOW in the study area b) does CObOW occurs randomly across the study area? c) are there spatially persistent areas of high (and low) obesity rates across the area under investigation? and c) are there any differences between male and female childhood obesity spatial patterns?

2. Data

CObOW data derived from a national school-based health survey (Tambalis et al., 2010). Specifically, anthropometric data and information on age, gender, city and area were collected, between May 1 and June 15, of 2008, in almost all schools of Primary Education (more than 85%n the study area). In this paper we analyse data concerning 24058 students (8 to 9- year-old children) of the primary schools of Attica prefecture. The 51,05% of the students are males. Standard body mass index (BMI) (kg/m^2) was adopted as the most proper obesity evaluator for epidemiologic studies (World Health Organization, 1995). BMI cut-off points were used by age and sex category (according to IOTF) for underweight, normal weight, overweight, and obese (Cole et al., 2000 and 2007). Here we present the analysis for overweight and obese children.

3. Methodology

In order to visualize and analyse spatial patterns of Childhood Obesity and Over Weight (CObOW), GIS technology was adopted. This technology is the most promising for the spatial clustering analysis of epidemiological data. The following GIS-supported procedures were implemented: a) Spatial Database creation, b) Geocoding – Aggregation of data c) Visualization in the form of various thematic maps and d) Assessment of spatial clustering. The spatial database was created in GIS context with the use of ArcGIS software package (Arctur and Zeiler, 2004). This geodatabase consists of thematic layers representing the administrative districts (area topology) according to the most recent "Kallikratis" administration plan (Figure 1) and the primary schools (point topology) of Attica prefecture. Next, we proceed to the geocoding and the aggregation of CObOW data. For this task the address of each school as well as the thematic layer of administrative units (municipalities) were used. With this procedure the allocation of each primary school in the spatial background of the study area was implemented. The aggregation of CObOW data related to the summation of CObOW cases in order to calculate the total number of disease cases in each administrative unit. These counts were expressed next as proportion of the population size (incidences per 1000 children) in order to estimate the prevalence of the phenomenon under investigation.



Name	Code
Filadelfeia - Chalkidona	01
Papagou - Xolargos	02
Dafni - Imittos	03
Kifissia	04
Penteli	05
Moschato - Tavros	06
Filothei - Psychiko	07
Likovryssi - Pefki	08
Elliniko - Argyroypoli	09
Ilion	10
Ag. Anargyroi - Kamatero	11
Athinai	13
Vyronas	14
Kallithea	15
Kaisariani	16
Iraklio	17
Ilioupoli	18
Zografou	19
Galatsi	20
Vrilissia	21
Maroysi	22
Alimos	23
Egaleo	24
Ag. Dimitrios	25
Ag. Paraskevi	26
Ag. Varvara	27
Glyfada	28
Petroupoli	29
Chalandri	30
Chaidari	31
Peristeri	32
Palaio Faliro	33
Nea Ionia	34
Metamorfosi	35
Nea Smirni	36
Keratsini - Drapetsona	37
Nikaia - Ag. Ioannis Renti	38
Peiraias	43
Perama	44
Korydallos	45
Oropos	50
Marathonas	51
Rafina - Pikermi	52
Dionisos	53
Achames	54
Pallini	55
Paiania	56
Spata - Artemida	57
Lavreotiki	58
Saronikos	59
Vari - Voula - Vouliagmeni	60
Kropia	61
Markopoylo Mesogaias	62
Elefsina	63
Mandra - Idillia	64
Megara	65
Fyli	66
Aspropyrgos	67

Figure 1: Study area – Attica prefecture and administrative units (municipalities according to "Kallikratis" plan)

This action is typical for spatial epidemiological analysis. Pfeiffer et al., (2008) underline that: "*Accounting the population at risk by using regional incidence rates, instead of regional disease counts, increase the likelihood that any observed autocorrelation deflects a genuine spatial pattern than a heterogeneous population distribution*". The visualisation and mapping of spatial properties of an epidemic dataset is the primary stage almost in every spatial epidemiological analysis (Pfeiffer et al., 2008:17). Thus, the first stage of our analysis was the creation of choropleth maps of CObOW rates for the study area. For the creation of these maps CObOW prevalence was calculated for each spatial unit (obese / overweigt children per 1000 children). As an output of this effort, various maps were created for male, female, and overall obesity and overweight children. The analysis of spatial clustering with the use of global and local indicators of spatial autocorrelation was the next stage of the methodology adopted. For the evaluation of spatial autocorrelation, in global level Moran's I (Moran, 1948) indicator was used, with the formalization from Ord and Getis (1995):

$$I = \frac{n \sum_i \sum_j w_{ij} z_i z_j}{w \sum_{i=1}^{n} z_i^2}$$

Equation 1

In this formula n is the number of spatial entities, $z_i = x_i - \bar{x}$, $\bar{x}$ is the mean value of x, $w = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$, and w_{ij} are the elements of the spatial contiguity matrix W. This matrix is an assessment of the spatial relationship between entities i and j. We assumed $w_{ij}=1$ when j is one of the neighbor entities of I *(Queen contiguity)* and $w_{ij}=0$ elsewhere. Area based methods (for local spatial clustering) detect if nearby areas have similar attributes. In that case, a positive spatial autocorrelation is flagged. Anselin (1995) by manipulating appropriately the above mentioned global clustering indicator proposed a Local Indicator for Spatial Autocorrelation (LISA). LISA is the local version of Moran index. This method performs a very unique analysis in the sense that instead of aiming in global clustering, aims to the identification of local patterns and local interactions. Local patterns are pointed out as local areas having excess values of LISA. In light of the above discussion, in this paper, we use LISA in order to reveal local associations.

The calculations of Global Moran's I , the creation of the spatial contiguity matrix W, and the creation of LISA maps were implemented with the use of GeoDa freeware package (Anselin 2003) and ArcGIS 9.3 software package.

4. Results

The aforementioned methodology utilized firstly to the creation of various choropleth maps of CObOW prevalence in Attica prefecture. Figure 2 demonstrates the most important of these maps. The interpretation of overall rates of obesity and overweight (maps figure 2c and figure 2d respectively) shows that only for 4 municipalities (ID codes: 01, 05, 28, 64) the childhood obesity rate is less than 5%, and only for 2 municipalities (ID codes: 08, 64) the overweight rate is less than 15%. On the contrary, for 10 municipalities the childhood obesity rate is > 15%, and for 33 municipalities the childhood overweight is > 25%. Additionally the spatial distribution of overall CObOW shows that low rates are concentrated in semi-urban municipalities at the north and east part of the prefecture. In the dense populated municipality of Athens obesity rate is in the range of 5%-10% while overweight rate exceeds 25%. From the comparison of male and female obesity maps (maps figure 2a and figure 2b respectively) it is evident that male obesity is more clustered. Furthermore, we have to notice that for 5 municipalities (ID Codes: 08, 27, 31, 35, 65) male obesity rates exceed 20%. The comparison of male and female overweight maps (figure 2e and figure 2f respectively) shows that both male/female high overweight rates are clustered. For 10 municipalities (ID Codes: 04, 05, 09, 16, 20, 25, 28, 36, 58, 62) male overweight rates are > 30%. These municipalities are concentrated to the central and southern part of the prefecture. High rates of female overweight are concentrated in the central part of the prefecture. For 7 municipalities (ID Codes: 06, 10, 09, 18, 27, 28, 36) female overweight rates exceed 30%. As mentioned in the methodology section of this paper, global Moran's I analysis quantifies the similarity of CObOW rates among spatially related geographical units. Thus, by using Geoda software a first order contiguity weight matrix (queen contiguity) was defined in order to assign spatial relations between municipalities. This matrix was used to calculate Moran's I (with Monte Carlo simulation and 9999 permutations) for male, female and overall childhood obesity and overweight incidence rates. These indicators (Table 1) show positive spatial autocorrelation (with the exception of female obesity) in CObOW incidence rates of neighbouring municipalities.

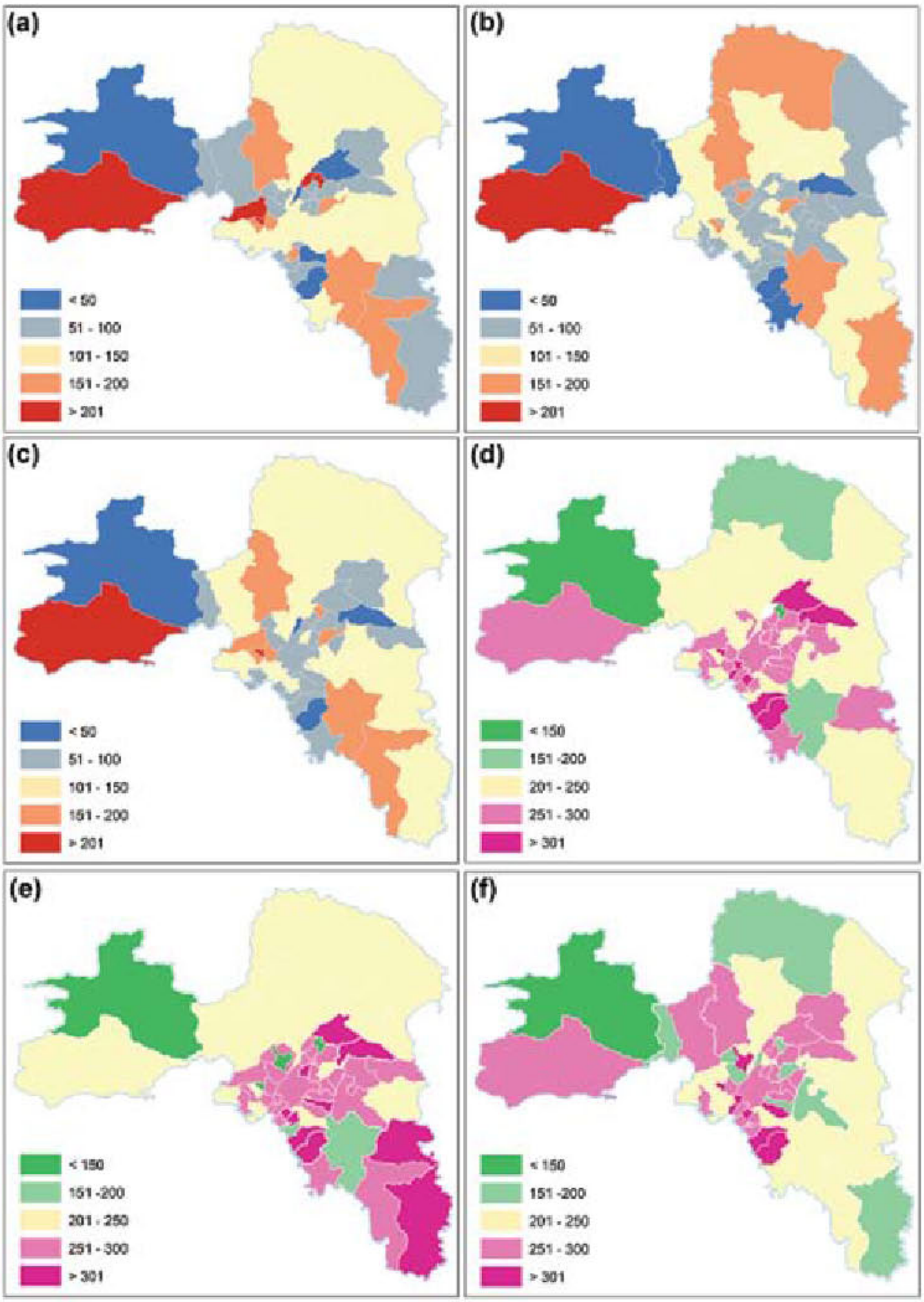


Figure 2: Choropleth maps of childhood Obesity (a, b, c) and Overweight (d, e, f) rates (indices per 1000 children). (a) and (e) maps refer to male rates, (b) and (f) to female rates, while (c) and (d) are overall (male + female) rates

Table 1: Moran's I Indicators of spatial autocorrelation

Incidence rate	**Moran's I**		
	Male	***Female***	***Total***
Obesity	0.0405	-0.0512	0.1066
Overweight	0.2778	0.2648	0.3188
Obesity & Overweight	0.2240	0.1895	0.2478

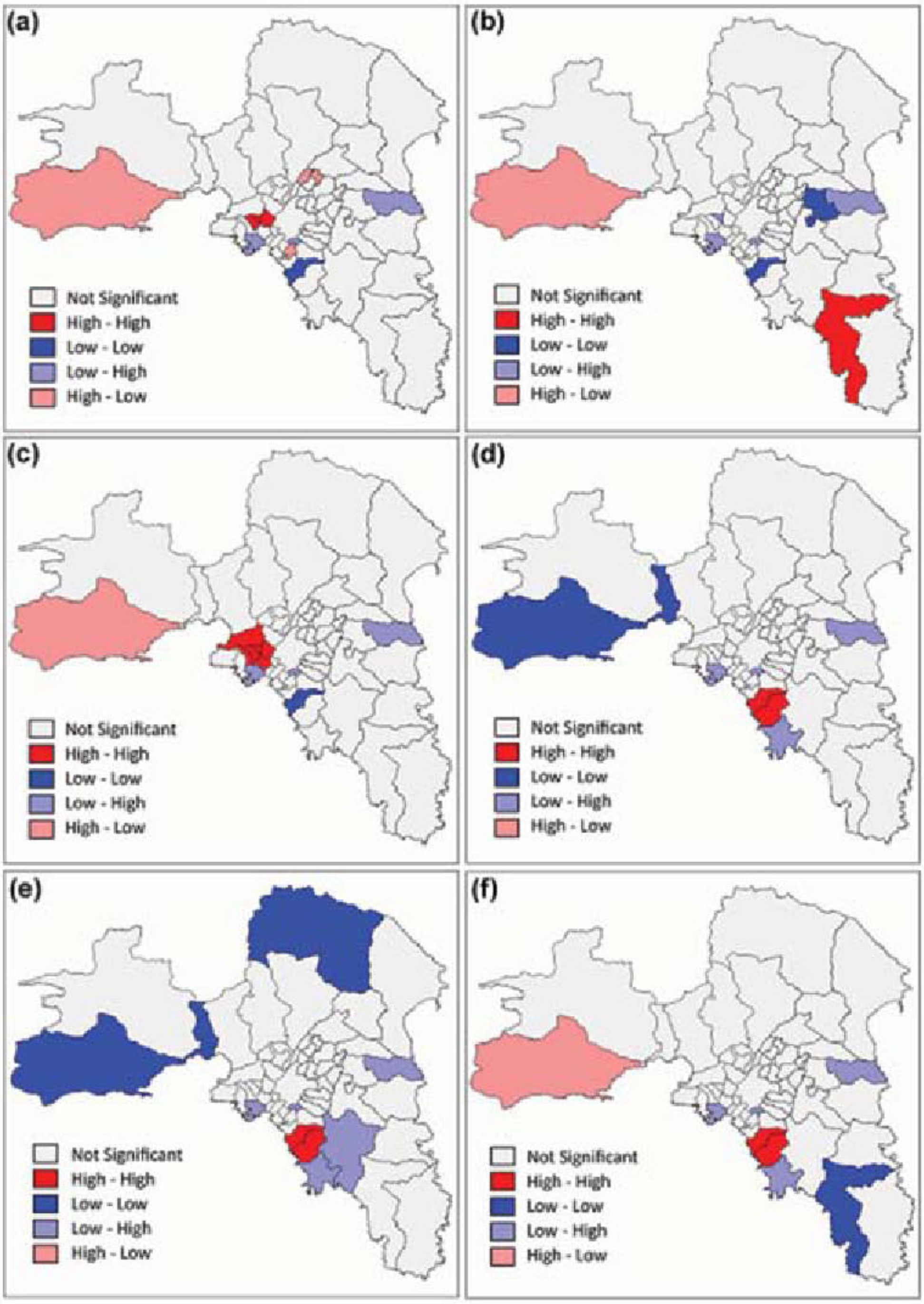


Figure 3: Spatial patterns of childhood obesity (a, b, c) and overweight (d, e, f) rates based on LISA analysis. (a) and (e) maps refer to male patterns, (b) and (f) to female, while (c) and (d) are overall (male + female) patterns

The comparison of Moran's I between male and female rates shows that male CObOW is more spatially autocorrelated than female. Additionally, positive spatial autocorrelation is more evident for overall, and/or overweight rates. In order to identify spatial patterns of CObOW we performed the local indicator of spatial association (LISA) analysis. This analysis evaluates the contribution of each location to the Moran's I Statistic for the whole area. Figure 3 shows the cluster maps after 5% significance filtering, and 9999 permutations of randomization (Monte Carlo technique). These cluster maps visualise the significant patterns by type of spatial association. After applying the LISA analysis for overall obesity (map figure 3c) a geographical area located in the southwest part of the prefecture was identified as the most significant hot spot (H-H) cluster (municipalities with ID Codes: 24, 27, 31, 38, 45). The same stands for male obesity (map figure 3a) while female obesity seems to occur more randomly in the study area (map figure 3b). LISA analysis of childhood overweight incidence rates identified a significant hot spot (H-H pattern) clustering (maps figure 3d, figure 3e, figure 3f) in the south part of the prefecture (municipalities with ID Codes: 09, 28). This cluster is the most important in both male and female LISA analysis. Low-Low clusters of overweight are limited and located mainly in suburban areas. Low-High clusters are evident in both obesity and overweight analysis in the central part of the study area (municipalities with ID Codes: 03, 43, 52).

5. Discussion - Conclusions

This study presents the spatial distribution and the spatial clustering of childhood obesity/overweight in Attica prefecture, Greece with the use of GIS technology. The produced thematic maps, confirm the significant CObOW incidence rates across the study area. These maps shows that female obesity seems to occur more or less homogenously within the study area while male obesity and male/female overweight incidences are more clustered. The global spatial autocorrelation analysis with the use of Moran's I indicator seem to confirm this first finding. The analysis of CObOW spatial clustering was carried out with the use LISA analysis. This analysis reveals hotspots of male childhood obesity and male/female overweight. The examination of the CObOW spatial patterns for Attica prefecture shows that there is a spatial cluster of male obesity in the southwest part of the prefecture while the most significant overweight cluster is located in the south part of Attica. The finding of the High- Low cluster, in some pockets of the study area, for both obesity and overweight is of major importance as these pockets possibly concentrate less favorable conditions for childhood obesity/overweight development. Variations in the spatial distribution of overweight and obesity could be related – among other reasons – with variations in socioeconomic conditions, educational level, environmental conditions, cultural norms and every-day practices (Tremblay et al., 2005, Pouliou and Elliott, 2009). The main advantage of LISA method is the quantification of spatial patterns on a detailed scale with the conceptualization of spatial relationships between spatial entities (spatial weights definition). Another advantage of the LISA method is the ability to identify all types of dependences: high-high values, low-low values, high-low values. This could prove very useful for the detailed interpretation of various spatial patterns of obesity. The spatial analysis of childhood obesity/overweight rates across Attica prefecture shows spatial differences especially between obesity– overweight and/or male – female rates. The identification of spatial patterns with the use of GIS technology provides useful information about geographical variation of CObOW. The results of the proposed analysis show significant High - High obesity clustering in Egaleo, Ag. Varvara Haidari, Korydallos and Nikea-Ag. Ioannis Rentis municipalities (in the south-west part of Attica) as well as significant High - High clustering for both overweight males and females in South Attica (municipalities of Elliniko - Argyroupoli, Glyfada). We have to underline as well the existence of the Low – High spatial cluster for both obesity and overweight in Peiraias, Dafni-Imittos and Rafina-Pikermi municipalities. In the future, childhood obesity data might be analysed within GIS context in cooperation with other geographical information in order to distinguish important correlations with environmental and socioeconomic data. Moreover, the exploratory geospatial research of childhood obesity/overweight in more detail local level could contribute to investigate potential spatial clustering in micro scale (neighbourhood level).

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