

ENVIRONMENTAL DETERMINANTS

The Association between Leisure-Time Physical Activities and Asthma Symptoms among 10- to 12-Year-Old Children: The Effect of Living Environment in the PANACEA Study

RENA I. KOSTI, PH.D.,¹ KOSTAS N. PRIFTIS, M.D., PH.D.,^{2,3} MICHAEL B. ANTHRACOPOULOS, M.D., PH.D.,⁴
ANASTASIOS PAPADIMITRIOU, M.D., PH.D.,³ DIMITRA GRIGOROPOULOU,¹ YIANNIS LENTZAS, PH.D.,¹
KONSTANTINA YFANTI,¹ AND DEMOSTHENES B. PANAGIOTAKOS, PH.D.^{1,*}

¹Department of Nutrition and Dietetics, Harokopio University, Athens, Greece.

²Department of Allergy-Pneumology, Penteli Children's Hospital, Athens, Greece.

³Third Department of Pediatrics, Attikon Hospital, University of Athens Medical School, Athens, Greece.

⁴Respiratory Unit, Department of Paediatrics, University of Patras Medical School, Patras, Greece.

Objective. This study evaluated the interrelationships of living environment, physical activity, lifestyle/dietary habits, and nutritional status on the prevalence of childhood asthma. **Methods.** In a cross-sectional survey 1125 children (529 boys), 10 to 12 years old, were selected from 18 schools located in an urban environment (Athens, $n = 700$) and from 10 schools located in rural areas ($n = 425$) in Greece. **Results.** Children living in Athens had higher likelihood of “ever had” asthma compared with children living in rural areas (odds ratio (OR) = 1.78, 95% confidence interval (CI) = 1.25–2.54), after adjusting for age and sex. After adjusting for age, sex, body mass index, and adherence to the Mediterranean diet (KIDMED score), leisure-time physical activity was inversely associated with “ever had” asthma. When stratifying by county of residence, a trend toward reduced asthma symptoms among children engaged in outdoor physical activities during their leisure time who reside in rural (but not urban) environment was observed (OR = 0.88, 95% CI = 0.77–1.01). **Conclusions.** The inverse relationship between asthma symptoms and leisure-time physical activity in the rural environment and the lack of an association between asthma symptoms and organized sports-related activities should draw the attention of public healthcare authorities. Their efforts should focus on the planning of a sustainable natural environment, which will promote the physical health of children and reduce the burden of childhood asthma.

Keywords asthma, children, environment, lifestyle, physical activity

INTRODUCTION

Literature suggests that the development of asthma is the result of gene–environment interaction (1). However, the increase in the prevalence of asthma (2) in the last 50 years has been attributed to various environmental and lifestyle changes, as the expression of alterations in genetic makeup requires a time span of several generations (3). According to the United Nations definition, living environment is defined as “urban” when it is characterized by high population density, housing in multi-apartment buildings, and high-level functions. On the other hand, “rural” environment traditionally involves low population density, living in separate houses, and agricultural/farming occupation (4). Researchers have shown that particular characteristics of urban living such as sedentary lifestyle, excess caloric intake, clustering within homes, car transportation, and high exposure to air pollution have important consequences on children's health (5), while processed and synthetic foods in conjunction with less fish, fruit, and vegetable intake have also been implicated in allergic inflammation (6).

The shift toward a sedentary lifestyle is considered to be an important risk factor of asthma symptoms (7, 8). Our group has previously shown an inverse association

between body mass index (BMI) and asthma symptoms (9, 10). Evidence suggests that in recent decades children spend increased amount of time indoors, occupying themselves with television viewing and occupation with electronic media and less time engaged in outdoor unstructured play (11). Although decreased physical activity can result from poorly controlled asthma, recent work has suggested that physical activity exerts a protective effect on asthma symptoms (9, 12–14). Furthermore, children living in rural environment appear to be at a lower risk of asthma than their urban counterparts (15–17).

Despite the aforementioned reported associations, the integrated influence of living environment, physical activity, lifestyle, dietary habits, and nutritional status on the prevalence of childhood asthma has not been investigated. Thus, in this study we sought to evaluate the interactions among physical activity, lifestyle/dietary habits, and nutritional status on the prevalence of asthma in 10- to 12-year-old children residing in an urban environment (i.e., Central Athens area) and two rural areas (i.e., Ilia, south of Athens, and Viotia, north of Athens) in Greece.

METHODS

Study's Sample

The extended Physical Activity, Nutrition and Allergies in Children Examined in Athens (PANACEA) study took

*Corresponding author: Demosthenes B. Panagiotakos, Department of Nutrition and Dietetics, Harokopio University, Athens, Greece; Tel: +30210 9603116; Fax: +30210 9600719; E-mail: d.b.panagiotakos@usa.net

place during 2005–2009 (12). It included 700 students aged 10–12 years from 18 schools located in various districts of Central Athens, 300 students from 7 schools located in Ilia county and 125 students from 3 schools located in Viotia county of the same age distribution. The schools were randomly selected from a list provided by the regional education offices, and the sampling was equally distributed between September and May for all areas. Overall, 1125 students (529 boys and 596 girls) aged 10–12 years were voluntarily enrolled in the study. Only premenstrual girls were included and the overall participation rate was 83.5%. The total number of enrolled children ($n = 1125$) was deemed adequate in order to evaluate the differences in odds ratios (ORs) between the various groups of study equal to 1.20 at probability level $<.05$ and achieve statistical power equal to 77% (G-Power free software, Kiel University, Kiel, Germany).

MEASUREMENTS

Evaluation of Asthma Symptoms

Asthma symptoms were evaluated using the International Study of Asthma and Allergies in Childhood (ISAAC) (18) standardized and validated self-administered questionnaire. More specifically, the duration and the assessment of asthma symptoms was based on four questions regarding whether the child (1) ever had wheezing; (2) ever had disturbed sleep due to wheezing; (3) ever had asthma; and (4) ever had dry cough at night, excluding cases of cold or chest infection.

Evaluation of Physical Activity Status during Leisure Time and Sports

Physical activity status was evaluated using a relevant questionnaire that has been shown to be a reliable and valid instrument of physical activity in children (19). The 30 questions of this tool include information on the duration, the frequency, and the intensity of several types of sport and non-sport activities. The questionnaire also includes information on the time spent in activities such as watching television and playing video games. The questionnaire was completed by the children, with the assistance of their parents, when needed. A detailed description of the questionnaire has been presented elsewhere (10). Definitions of physical activity are as follows: (1) “*leisure time physical activity*” includes unstructured outdoor physical activity of the child spent in play with friends outdoors, walking, cycling, and so on; (2) “*sports-related activity*” is defined as those structured athletic activities (soccer, basketball, tennis, swimming, and other team sports) during off-school hours; and (3) “*any type of physical activity*” includes both leisure time (unstructured) and sports-related activities. Physical activities during school hours were not included in the analysis; these represent a (almost) constant factor for all children as they comply with the directions of the National Ministry of Education to all schools.

Dietary Evaluation and Adherence to the Mediterranean Diet

Dietary evaluation was based on a validated semi-quantitative Food Frequency Questionnaire, which was designed for the study and was completed by the children with the assistance of their parents, when needed (20). Adherence to the Mediterranean diet was evaluated using the KIDMED index (Mediterranean Diet Quality Index for children and adolescents) (21). The total score was divided into three categories: (1) ≥ 8 , optimal diet; (2) 4–7, improvement needed to adjust intake to Mediterranean patterns; and (3) ≤ 3 , very low diet quality.

Evaluation of Socio-Demographic and Anthropometric Characteristics

Information on socio-demographic characteristics (age, sex, parental occupation, and income) was also retrieved; it is described in detail elsewhere (10). Standing height to the nearest 0.1 cm after children had removed their shoes and body weight to the nearest 0.1 kg on calibrated digital scales were measured using standard procedures. BMI was calculated and the children were classified as normal, overweight, or obese by using the international cutoff points for BMI for overweight and obesity according to sex between 2 and 18 years (22). Information on birth weight was obtained from the child’s personal health booklet.

Geo-Climatic Information of Cities

Macro-environment was one of the target factors evaluated in this work. Climatic data such as relative humidity, temperature, and average rainfall of the sampled urban and rural areas are presented (23). Athens is the capital and the largest city in Greece and is characterized as an urban area with high population density. Its climate is drier compared with other Greek cities, with relative humidity ranging from 46.7% to 70.1% and temperature ranging from -3.2°C to 42.0°C . The average rainfall in the area is 5.2–64.1 mm, and the air pollution is characterized by high concentrations of particles and photochemical smog. All schools surveyed were within the center city area. On the other hand, the surveyed areas of Ilia and Viotia are open country rural areas with low population density. In detail, *Ilia* is a county in Western Greece (to the south of Athens), which consists of a flat agricultural area with relative humidity from 62.9% to 79.4%, temperature range from -5.8°C to 42.4°C , and average rainfall from 4.5 mm to -194 mm. *Viotia* is settled in Central Greece (to the north of Athens) and consists of flat and mountainous areas with agricultural and industrial development. Viotia’s average temperature ranges from -2.6°C to 41.1°C , average relative humidity ranges from 47.6% to 74.6%, and average rainfall ranges from 7.0 mm to 99.3 mm. Based on the above data, it is deduced that the climatic differences between the urban and the rural areas of the study are not extremely pronounced apart from the fact that Athens city is characterized by high photochemical smog. Although there are no available relevant data

from the rural areas, it is worth mentioning that Viotia is expected to have a higher concentration of atmospheric particle load due to its more industrialized characteristics compared with Ilia.

Bioethics

The study was designed according to the principles of the Declaration of Helsinki (1989). The protocol of the study was approved by the Research Department of the Education Institute of the Hellenic Ministry of Education, which is the government office responsible for granting ethical approval in order to perform studies in school settings (approval number 29712/G7/2006).

Statistical Analysis

All continuous variables are presented as mean $\pm$ SD and categorical variables as frequencies. Associations between categorical variables were tested using the χ^2 -test, and comparisons between proportions were evaluated using the Z-test. Comparisons between mean values were evaluated using the Student's *t*-test, after checking for normality of distributions or the Mann–Whitney test. To assess the relationship between asthma symptoms and leisure time activities multiple logistic regression analysis was applied, adjusting for various factors that were considered to be potential confounders or effect mediators. The results are presented as ORs and their corresponding 95% confidence intervals (CIs). Hosmer–Lemeshow statistic was calculated in order to evaluate the model's goodness of fit. All reported probability values (*p*-values) were based on two-sided hypothesis and compared with a significance level of 5%. SPSS 18 software was used for all the calculations (SPSS Inc., Chicago, IL, USA).

RESULTS

Urban/Rural Environment and Asthma Symptoms

The prevalence of asthma symptoms (i.e., current and ever had) is presented by area of residence in Table 1. Since there was no difference in the prevalence of asthma symptoms between the two rural areas ($p = .29$), these were combined in the analysis. The overall asthma prevalence was 23.7% (boys, 27.6%; girls, 20.4%; $p = .03$) in the urban area of Central Athens and 14.6% (boys, 18.4%; girls, 11.0%; $p = .01$) in the (combined) rural environment of the study. Data analysis showed that the prevalence of asthma symptoms was higher in the urban compared with the rural environment ($p < .001$).

Moreover, as previously reported (10), children living in Central Athens showed 1.78 times higher likelihood of exhibiting asthma symptoms compared with those residing in rural areas (OR = 1.78, 95% CI = 1.25–2.54), after adjusting for age and sex.

Physical Activities, Dietary Habits, Lifestyle, and Asthma Symptoms

A highly significant overall association was observed regarding living area and “any type of physical activity”

TABLE 1.—Prevalence of asthma symptoms among 10- to 12-year-old children living in urban (Athens) and in rural areas (Ilia and Viotia).

	Urban areas, Athens (<i>n</i> = 700)	Rural areas, Ilia and Viotia (<i>n</i> = 425)	<i>p</i>
Any asthma symptoms (ever) (%)	23.7	14.6	<.001
Current asthma (%)	7.0	11.0	.05
Night cough (ever) (%)	12.8	13.2	.85
Exercise wheeze (ever) (%)	4.5	4.1	.72
Wheeze-limiting speech (ever) (%)	5.1	1.8	.15
Wheeze disturb sleep (ever), %			<.001
<1 time/week	19.6	3.3	
>1 time/week	6.6	7.3	

Note: *P*-values are derived using χ^2 -test.

(prevalence of physical activity in urban vs. rural areas: 52% vs. 67%, $p < .001$). Further analysis revealed that only “leisure time activity” was inversely associated with asthma symptoms (asthmatic: 1.6 ± 1.6 vs. non-asthmatic: 2.1 ± 2.0 times/week, $p < .001$). No significant association was observed regarding organized “sports-related activity” ($p = .17$) or “any type of physical activity” ($p = .86$).

Socio-demographic and lifestyle habits of 10- to 12-year-old asthmatic and non-asthmatic children with regard to their place of residence are presented in Table 2. In particular, when the analysis was stratified by asthma symptoms, it revealed that children living in urban environment were less likely to adhere to a Mediterranean dietary pattern (as reflected by a lower total KIDMED scores, $p < .01$) compared with children living in rural areas, irrespective of the status of their asthma symptoms. In addition, children living in urban areas were less likely to be engaged in “leisure time physical activity” compared with those living in rural areas, irrespective of asthma symptoms' status (Table 2).

Urban/Rural Environment, Leisure Time Physical Activity, and Asthma Symptoms

Unadjusted analysis showed that “leisure time physical activity” was inversely associated with asthma prevalence (OR = 0.85, 95% CI = 0.77, 0.93). However, despite this association, residual confounding may still exist. Thus, multiple logistic regression analysis was applied (Table 3) in order to evaluate “leisure-time physical activity” of children in relation to the prevalence of asthma symptoms, after taking into account potential confounders. It is evident that after adjusting for age, sex, BMI, and KIDMED score (Table 3; models 1, 2, and 3), “leisure time physical activity” still showed an inverse association with asthma symptoms. However, when the living environment factor (i.e., rural vs. urban) was entered in the model the association between “leisure time physical activity” and asthma ceased to be significant (Table 3; model 4). It is noted that no association was observed between asthma symptoms and either “any type or sports-related physical

TABLE 2.—Socio-demographic and lifestyle habits of 10- to 12-year-old asthmatic and non-asthmatic children with regard to their place of residence.

	Asthma, <i>n</i> = 228		<i>p</i>	Non-asthma, <i>n</i> = 897		<i>p</i>
	Urban (<i>n</i> = 166)	Rural (<i>n</i> = 62)		Urban (<i>n</i> = 534)	Rural (<i>n</i> = 363)	
Age	11.2 ± 0.7	11 ± 0.7	.11	11.2 ± 0.8	11.3 ± 0.7	.08
Boys (%)	54.2	61.3	.33	43.6	46.3	.43
BMI (kg/m ²)	20.6 ± 3.7	20.4 ± 3.6	.75	20.2 ± 3.7	19.1 ± 3	<.001
Overweight/obese (%)	27.9	37.7	.38	27.5	26.3	<.001
KIDMED score (0–12) ^a	4.1 ± 1.6	4.8 ± 2.0	.007	4.9 ± 2.0	5.3 ± 2.0	.002
KIDMED score ≥8 ^b (%)	2.4	4.8	.02	14.4	14.9	.001
Any physical activity (%)	54.2	66.1	.10	32.5	67.5	<.001
Leisure time (times/week)	0.9 ± 0.3	3.3 ± 2.3	<.001	0.9 ± 0.5	3.7 ± 2.2	<.001
Sports activity (times/week)	4.0 ± 3.6	3.3 ± 2.7	.16	3.5 ± 2.8	3.3 ± 3.0	.33
TV/video games (hours/day)	2.4 ± 1.2	2.2 ± 1.1	.39	2.2 ± 1.3	2.3 ± 1.3	<.001

Notes: BMI, body mass index.

P-values are derived using χ^2 -test for the categorical variables, Student's *t*-test for the normally distributed (i.e., age and BMI), or Mann–Whitney test for the skewed.

^aAdherence to the Mediterranean diet was assessed using the Mediterranean and Diet Quality Index for children and adolescents (KIDMED) score.

^bKIDMED ≥8 suggests an optimal diet (21).

TABLE 3.—Results from additive multiple logistic regression models that evaluated the prevalence of asthma symptoms in 10- to 12-year-old children from urban (Athens) and rural (Ilia and Viotia) areas.

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Age (per 1 year)	0.84 (0.67, 1.04)	0.80 (0.64, 1.00)	0.82 (0.65, 1.03)	0.82 (0.66, 1.03)
Boys <i>versus</i> girls (reference category)	0.62 (0.45, 0.85)*	0.66 (0.47, 0.91)*	0.64 (0.46, 0.90)*	0.65 (0.46, 0.90)*
Leisure-time activities (Y/N)	0.85 (0.77, 0.93)*	0.85 (0.77, 0.94)*	0.87 (0.77, 0.96)*	0.90 (0.79, 1.03)
BMI (per 1 kg/m ²)	—	1.06 (1.02, 1.11)*	1.06 (1.01, 1.10)*	1.05 (1.01, 1.10)*
KIDMED score (per 1 unit)	—	—	0.83 (0.76, 0.90)*	0.83 (0.76, 0.91)*
Rural <i>versus</i> urban (reference category)	—	—	—	1.27 (0.77, 2.08)

Notes: BMI, body mass index. OR, odds ratio; 95% CI, 95% confidence interval.

**p* < .01.

activity,” after adjusting for all the covariates included in model 4 (data not shown). When the analysis was stratified by area of residence, it was observed that there was a protective trend against asthma symptoms with the engagement of children in outdoor “leisure-time physical activity” *only* among children living in rural areas (OR = 0.88, 95% CI = 0.77–1.01); indeed, no such trend was observed in children who lived in urban areas (OR = 1.13, 95% CI = 0.77–1.66).

Furthermore, the inverse association between BMI and asthma symptoms was sustained in all models, showing that increased BMI was associated with a higher odds of asthma symptoms (OR = 1.05, 95% CI = 1.01, 1.10), regardless of area of residence. However, further analysis revealed that this association was significant only in the rural environment (37.7% overweight among asthmatics vs. 26.3% overweight among non-asthmatics, *p* = .004 for rural areas; 27.9% overweight asthmatics vs. 27.5% overweight non-asthmatics, *p* = .608 for urban areas) (data not shown).

DISCUSSION

Within the context of PANACEA study, we tested the hypothesis that there is an interrelationship of living environment, physical activity, lifestyle/dietary habits, nutritional status (BMI), and prevalence of asthma among 10- to 12-year-old children. We found a trend toward a

protective effect against asthma symptoms when children were engaged in outdoor physical activities during their leisure time. However, this trend was sustained only in the rural environment when the two living areas were examined separately. Therefore, our findings suggest that residing in an urban compared with a rural area results in the loss of the potential protective effect of unstructured physical activity on asthma symptoms.

Moreover, in agreement with previous findings of our group (9, 10) and those of others (8, 24), we showed that the increased BMI results in the deterioration of asthma symptoms. Still, the finding that the BMI was positively associated with the prevalence of asthma symptoms *only* in the rural areas suggests that within an urban environment lifestyle and/or environmental factors other than overweight and obesity play a more prominent role in determining the prevalence of asthma symptoms.

The results of the PANACEA study have suggested that the prevalence of asthma symptoms in urban environment is higher than that of rural areas. This has been confirmed by a number of studies that have shown a marked difference in the prevalence of asthma between urban and rural regions with asthma and wheezing prevailing in the urban environment (10, 15–17).

Indeed, literature suggests that the area of residence and residential environmental risk factors affect the prevalence of childhood asthma (17, 25). Majkowska-Wojciechowska et al. (26) showed that residing in a rural environment is

associated with lower prevalence of allergic sensitization and allergic symptoms among schoolchildren and concluded that several environmental and lifestyle risk and protective factors in both rural and urban environments are probably responsible for these findings. Our study shows that boys carry a higher risk of exhibiting asthma symptoms compared with girls in both environments. This finding is in agreement with other literature that suggests that asthma is more frequent in boys than in girls before puberty, while the gender ratio is reversed in adulthood (27).

Regarding the differences in the prevalence of asthma symptoms between rural and urban areas, a number of explanations have been invoked in their explanation. The rapid increase in asthma prevalence in westernized societies has occurred in parallel with drastic change in diet, which is one of the hallmarks of westernization. Therefore, dietary factors may play a key role in affecting the complex genetic and developmental pathophysiology of asthma (28). It appears that the relationship between dietary patterns and place of residence reflects not only the differences in eating habits but also the abandonment of the traditional Mediterranean diet as an important consequence of urbanized lifestyle (29). Indeed, according to our findings, children living in urban areas were less likely to adhere to the Mediterranean dietary pattern, as reflected by lower total KIDMED scores compared with their peers that reside in rural areas. Considering that children who closely adhered to the Mediterranean diet had a lower likelihood of reporting asthma symptoms compared with those whose dietary habits deviated from this pattern in urban and rural areas alike (10, 30–32), it can be surmised that urban environment and lifestyle may, indeed, exert a strong influence on the nutritional habits of children.

Apart from dietary factors, a highly significant association was also observed between living area and physical activity (of any type). This finding is consistent with the results of previous studies, which have shown that rural environment enhances the physical activity of children (33, 34). The lower levels of physical activity observed in urban areas have been attributed, at least in part, to parental constraints due to the perceived risks regarding safety in city environments (35, 36).

In addition, the rural areas of Ilia and Viotia are characterized by greater humidity, lower temperature, and greater average rainfall as compared with the city of Athens. It is possible that these climatic conditions negatively affect the occurrence of asthma symptoms (37) and lead children to spend less time in outdoor play. However, our results show that children living in rural areas spend more time in outdoor physical activities as compared with their peers residing in the city; they also experience less asthma symptoms. These findings are in agreement with those reported by a recent review study, which found that children of rural areas spend more time in outdoor unstructured play as compared with those that reside in the city (38). Therefore, the advantages of residing in a rural environment may overcompensate for the adverse climatological conditions observed in the rural areas of this study regarding asthma prevalence.

Furthermore, current evidence has linked a number of physical and mental health benefits in children with unstructured outdoor activity and time spent by them in a natural environment such as a park or other recreational areas (11). Thus, the lack of natural environment for recreational activities in urban areas could be a critical confounding factor that cancels the association between leisure-time physical activities and asthma symptoms in children living in urban environment. Moreover, recent findings suggest that psychosocial distress (39), community violence, and crime (40) are associated with asthma; these phenomena, as expected, are more pronounced in urban areas. It has also been shown that air quality has deteriorated as a consequence of truck and other traffic-related air pollution, while traffic and respiratory diseases have increased among residents of urban environments (41, 42). In particular, the results of a Greek study show that nitrogen dioxide and sulfur dioxide were higher in an urban as compared with a rural area, whereas ozone concentrations differed less between the two (16).

It is worth mentioning that while environmental exposure of farm children to endotoxin has been associated with reduced prevalence of asthma and atopy, thus lending support to the hygiene hypothesis (43, 44), the findings of a Greek study showed that the negative association between rural living and the risk of atopy during childhood was independent of farming practices; perhaps the profound differences between the residential conditions of rural Greece (i.e., lack of large animals in close proximity to the residence) and the farming environment in Central Europe may account for this discrepancy (45).

Limitations

It should be noted that the PANACEA study is a cross-sectional survey and, therefore, cannot establish causal relationships; its findings can only be used to state hypotheses. Another limitation is the lack of measurements of lung function and detection of allergens. Moreover, it lacks objective assessment of physical activity, while dietary habits and asthma symptoms are self-reported. Another limitation is the lack of data on air quality, in particular concentrations of small particles in urban and rural areas. Lastly, although the sample size is relatively small when compared with large international surveys, the values of statistical power for all analyses were high (i.e., ~80%), and attention was paid not to over-interpret the findings.

CONCLUSIONS

The results of this study show that leisure-time outdoor physical activities of children residing in rural, but *not* urban, areas may confer protection against asthma symptoms. The understanding of the complex relationships between exposure and development of asthma symptoms is important for the planning of effective primary and secondary preventive strategies in order to reduce the burden of asthma. Public health policymakers need to focus their efforts on the planning of a sustainable natural

environment, which will promote the physical health of children and reduce the burden of childhood asthma.

ACKNOWLEDGEMENTS

The authors thank the field investigators of the “PANACEA” study: Adina Tsoutsou, Marios Papadopoulos, and Martha Harisi (pediatricians); Maria Konstantinidou (dietician); Dionysia Kounadi (visiting nurse); Nika Priftis (sports science specialist); and George Antonogiorgos (physician/biostatistician). The authors also thank the schoolteachers, the children, and their parents who participated in the study for their support.

DECLARATION OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

REFERENCES

- McLeish S, Turner SW. Gene–environment interactions in asthma. *Arch Dis Child* 2007; 92:1032–1035.
- World Health Organization. 2011. Fact sheet N°307. Available at: <http://www.who.int/mediacentre/factsheets/fs307/en/index.html>. Accessed July 22, 2011.
- Yeatts K, Sly P, Shore S, Weiss S, Martinez F, Geller A, Bromberg P, Enright P, Koren H, Weissman D, Selgrade M. A brief targeted review of susceptibility factors, environmental exposures, asthma incidence, and recommendations for future asthma incidence research. *Environ Health Perspect* 2006; 114(4):634–640.
- United Nations. Principles and Recommendations for Population and Housing Censuses. Revision 2. United Nations Expert Group Meeting on the 2010 World Programme on Population and Housing Censuses, 10–14 July 2006, United Nations, New York.
- Brunekreef B, Holgate ST. Air pollution and health. *Lancet* 2002; 360:1233–1242.
- West CE, Videky DJ, Prescott SL. Dietary polyunsaturated fatty acids in the prevention of allergic inflammatory conditions: progress and perspectives. *Clin Exp Allergy* 2010; 40(8):1113–1115.
- Hoyos Cillero I, Jago R. Sociodemographic and home environment predictors of screen viewing among Spanish school children. *J Public Health (Oxf)* 2011; 33(3):392–402.
- Corbo GM, Forastiere F, De Sario M, Brunetti L, Bonci E, Bugiani M, Chellini E, La Grutta S, Migliore E, Pistelli R, Rusconi F, Russo A, Simoni M, Talassi F, Galassi C; Sidria-2 Collaborative Group. Wheeze and asthma in children: associations with body mass index, sports, television viewing, and diet. *Epidemiology* 2008; 19(5):747–755.
- Priftis KN, Panagiotakos DB, Antonogeorgos G, Papadopoulos M, Charisi M, Lagona E, Anthracopoulos MB. Factors associated with asthma symptoms in schoolchildren from Greece: the Physical Activity, Nutrition and Allergies in Children Examined in Athens (PANACEA) study. *J Asthma* 2007; 44(7):521–527.
- Grigoropoulou D, Priftis KN, Yannakoulia M, Papadimitriou A, Anthracopoulos MB, Yfanti K, Panagiotakos DB. Urban environment adherence to the Mediterranean diet and prevalence of asthma symptoms among 10- to 12-year-old children: the Physical Activity, Nutrition, and Allergies in Children Examined in Athens study. *Allergy Asthma Proc* 2011; 32(5):351–358.
- McCurdy LE, Winterbottom KE, Mehta SS, Roberts JR. Using nature and outdoor activity to improve children’s health. *Curr Probl Pediatr Adolesc Health Care* 2010; 40(5):102–117.
- Priftis KN, Panagiotakos DB, Anthracopoulos MB, Papadimitriou A, Nicolaidou P. Aims, methods and preliminary findings of the Physical Activity, Nutrition and Allergies in Children Examined in Athens (PANACEA) epidemiological study. *BMC Public Health*. 2007 Jul 4;7:140.
- Tsai HJ, Tsai AC, Nriag J, Ghosh D, Gong M, Sandretto A. Association of BMI, TV-watching time, and physical activity on respiratory symptoms and asthma in 5th grade schoolchildren in Taipei, Taiwan. *J Asthma* 2007; 44:397–401.
- Onur E, Kabaroğlu C, Günay O, Var A, Yilmaz O, Dündar P, Tikiz C, Güvenç Y, Yüksel H. The beneficial effects of physical exercise on antioxidant status in asthmatic children. *Allergol Immunopathol (Madr)* 2011; 39(2):90–95.
- Arif AA, Borders TF, Patterson PJ, Rohrer JE, Xu KT. Prevalence and correlates of paediatric asthma and wheezing in a largely rural USA population. *J Paediatr Child Health* 2004; 40(4):189–194.
- Priftis KN, Anthracopoulos MB, Paliatatos AG, Tzavelas G, Nikolaou-Papanagiotou A, Douridas P, Nicolaidou P, Mantzouranis E. Different effects of urban and rural environments in the respiratory status of Greek schoolchildren. *Respir Med* 2007; 101(1):98–106.
- Wong GW, Chow CM. Childhood asthma epidemiology: insights from comparative studies of rural and urban populations. *Pediatr Pulmonol* 2008; 43:107–116.
- Weiland SK, Bjorksten B, Brunekreef B, Cookson WO, von Mutius E, Strachan DP; International Study of Asthma and Allergies in Childhood Phase II Study Group. Phase II of the International Study of Asthma and Allergies in Childhood (ISAAC II): rationale and methods. *Eur Respir J* 2004; 24:406–412.
- Argiropoulou E, Michalopoulou M, Aggeloussis N, Avgerinos A. Validity and reliability of physical activity measure in Greek high school age children. *J Sports Sci Med* 2004; 3:147–159.
- Antonogeorgos G, Grigoropoulou D, Papadimitriou A. Validation of a semi-quantitative Food Frequency Questionnaire designed for children aged 10–12 years: The PANACEA-FFQ [abstract]. *Hellenic J Atherosclerosis* 2010; 1:57.
- Serra-Majem L, Ribas L, Ngo J, Ortega RM, García A, Pérez-Rodrigo C, Aranceta J. Food, youth and the Mediterranean diet in Spain. Development of KIDMED, Mediterranean Diet Quality Index in children and adolescents. *Public Health Nutr*. 2004 Oct;7(7):931–5.
- Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; 320:1240–1243.
- Hellenic National Meteorological Service. Available at: <http://www.emy.gov.gr>. Accessed November 20, 2011.
- Yao TC, Ou LS, Yeh KW, Lee WI, Chen LC, Huang JL; PATCH Study Group. Associations of age, gender, and BMI with prevalence of allergic diseases in children: PATCH study. *J Asthma* 2011; 48(5):503–510.
- Hwang GS, Choi JW, Yoo Y, Choung JT, Yoon CS. Residential environmental risk factors for childhood asthma prevalence in metropolitan and semirural cities in Korea. *Asia Pac J Public Health* 2011 [Epub ahead of print].
- Majkowska-Wojciechowska B, Pełka J, Korzon L, Kozłowska A, Kaczala M, Jarzebska M, Gwardys T, Kowalski ML. Prevalence of allergy, patterns of allergic sensitization and allergy risk factors in rural and urban children. *Respir Med* 2007; 62(9):1044–50.
- Postma DS. Gender differences in asthma development and progression. *Gend Med*. 2007;4 Suppl B:S133–46.
- Kim J-H, Ellwood PE, Asher MI. Diet and asthma: looking back, moving forward. *Respir Res* 2009; 10:49.
- Lazarou C, Kalavana T. Urbanization influences dietary habits of Cypriot children: the CYKIDS study. *Int J Public Health* 2009; 54(2):69–77.
- Nagel G, Weinmayr G, Kleiner A, Garcia-Marcos L, Strachan DP, ISAAC Phase Two Study Group. Effect of diet on asthma and allergic sensitisation in the International Study on Allergies and Asthma in Childhood (ISAAC) phase two. *Thorax* 2010; 65(6):516–522.
- Arvaniti F, Priftis KN, Papadimitriou A, Papadopoulos M, Roma E, Kapsokefalou M, Anthracopoulos MB, Panagiotakos DB. Adherence to the Mediterranean type of diet is associated with lower prevalence of asthma symptoms, among 10–12 years old children: the PANACEA study. *Pediatr Allergy Immunol* 2011; 22(3):283–289.
- McCloud E, Papoutsakis C. A medical nutrition therapy primer for childhood asthma: current and emerging perspectives. *J Am Diet Assoc* 2011; 111(7):1052–1064.
- Sandercock G, Angus C, Barton J. Physical activity levels of children living in different built environments. *Prev Med* 2010; 50(4):193–198.

34. Ogunleye AA, Voss C, Barton JL, Pretty JN, Sandercock G. Contrasting physical activity patterns in children and adolescents living in differing environments in the UK. *Scand J Public Health* 2011; 39(7):696–703.
35. Jago R, Thompson JL, Page AS, Brockman R, Cartwright K, Fox KR. Licence to be active: parental concerns and 10–11-year-old children's ability to be independently physically active. *J Public Health (Oxf)* 2009; 31(4):472–477.
36. Carver A, Timperio A, Hesketh K, Crawford D. Are children and adolescents less active if parents restrict their physical activity and active transport due to perceived risk? *Soc Sci Med* 2010; 70(11):1799–1805.
37. Weiland SK, Hüsing A, Strachan DP, Rzehak P, Pearce N, ISAAC Phase One Study Group. Climate and the prevalence of symptoms of asthma, allergic rhinitis, and atopic eczema in children. *Occup Environ Med* 2004; 61(7):609–615.
38. Sandercock G, Angus C, Barton J. Physical activity levels of children living in different built environments. *Prev Med* 2010; 50:193–198.
39. Yorke J, Fleming SL, Shulldham C. A systematic review of psychological interventions for children with asthma. *Pediatr Pulmonol* 2007; 42(2):114–124.
40. Gupta RS, Zhang X, Springston EE, Sharp LK, Curtis LM, Shalowitz M, Shannon JJ, Weiss KB. The association between community crime and childhood asthma prevalence in Chicago. *Ann Allergy Asthma Immunol* 2010; 104(4):299–306.
41. Jerrett M, Shankardass K, Berhane K, Gauderman WJ, Künzli N, Avol E, Gilliland F, Lurmann F, Molitor JN, Molitor JT, Thomas DC, Peters J, McConnell R. Traffic-related air pollution and asthma onset in children: a prospective cohort study with individual exposure measurement. *Environ Health Perspect* 2008; 116(10):1433–1438.
42. Tzivian L. Outdoor air pollution and asthma in children. *J Asthma* 2011; 48(5):470–481.
43. Morcos MM, Morcos WM, Ibrahim MA, Shaheen MA. Environmental exposure to endotoxin in rural and urban Egyptian school children and its relation to asthma and atopy. *Minerva Pediatr* 2011; 63(1):19–26.
44. Mendy A, Gasana J, Vieira ER, Forno E, Patel J, Kadam P, Ramirez G. Endotoxin exposure and childhood wheeze and asthma: a meta-analysis of observational studies. *J Asthma* 2011; 48(7):685–693.
45. Priftis KN, Anthracopoulos MB, Nikolaou-Papanagiotou A, Matziou V, Paliatsos AG, Tzavelas G, Nicolaidou P, Mantzouranis E. Increased sensitization in urban vs. rural environment – rural protection or an urban living effect? *Pediatr Allergy Immunol* 2007; 18:209–216.

Copyright of Journal of Asthma is the property of Taylor & Francis Ltd and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.