Prevalence of Asthma among Young Men Residing in Urban Areas with Different Sources of Air Pollution

Nili Greenberg PhD[1,3], Rafael S. Carel MD DrPH[1], Jonathan Dubnov MD MPH[1], Estela Derazne MSc[3] and Boris A. Portnov PhD DSc[2]

[1]School of Public Health and [2]Department of Natural Resources and Environment Management, University of Haifa, Israel
[3]Israeli Defense Forces, Medical Corps, Israel

ABSTRACT: **Background:** Asthma is a common respiratory disease, which is linked to air pollution. However, little is known about the effect of specific air pollution sources on asthma occurrence.

Objective: To assess individual asthma risk in three urban areas in Israel characterized by different primary sources of air pollution: predominantly traffic-related air pollution (Tel Aviv) or predominantly industrial air pollution (the Haifa bay area and Hadera).

Methods: The medical records of 13,875, 16- to 19-year-old males, who lived in the affected urban areas prior to their army recruitment and who underwent standard pre-military health examinations during 2012–2014, were examined. Nonparametric tests were applied to compare asthma prevalence, and binary logistic regressions were used to assess the asthma risk attributed to the residential locations of the subjects, controlling for confounders, such as sociodemographic status, body mass index, cognitive abilities, and education.

Results: The asthma rate among young males residing in Tel Aviv was 8.76%, compared to 6.96% in the Haifa bay area and 6.09% in Hadera. However, no statistically significant differences in asthma risk among the three urban areas was found in controlled logistic regressions ($P > 0.20$).

Conclusions: Both industrial- and traffic-related air pollution have a negative effect on asthma risk in young males. Studies evaluating the association between asthma risk and specific air pollutants (e.g., sulfur dioxide, particulate matter, and nitrogen dioxide) are needed to ascertain the effects of individual air pollutants on asthma occurrence.

IMAJ 2019; 21: 785–789

KEY WORDS: air pollution, asthma, industry, residential exposure, transportation

Several studies conducted in Israel have examined the association between air pollution and respiratory morbidity in different regions of the country [1-5]. Most of these studies did not reveal a consistent effect of exposure to environmental air pollution on asthma prevalence. A comprehensive review by Greenberg et al. [4] attributed this ambiguity to the different research methodologies and different types of air pollution data used in different studies. Two studies by Greenberg and colleagues [6,7], which were based on individual data obtained for a large nation-wide cohort of young men, demonstrated higher prevalence rates of asthma in more polluted areas. The studies also showed a statistically significant association between asthma risk and residential exposure to nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) air pollutants. However, little is known about the effect of specific sources of air pollution on asthma prevalence.

BACKGROUND STUDIES

Air pollution from motor traffic and industries is significantly associated with respiratory morbidity in general and asthma morbidity in particular [8,9]. The number of motor vehicles in Israel rises constantly [10]. In addition to motor traffic, in many urban areas of the country there are industries that emit particulate matter (PM), SO_2, NO_x, and other chemicals, such as benzene, benzo(a)pyrene, heavy metals, and organic and inorganic substances [11].

Greenwald et al. [12] demonstrated that exposure to traffic-related air pollution increased airways inflammation and decreased lung function in asthmatic children in Texas, USA. According to the study forced expiratory volume in 1 second (FEV1) in asthmatic children declined by up to 5%, which was in concordance with an interquartile range increase in the concentration of volatile organic compounds from traffic sources. Buteau and colleagues [13] reported that residential exposure to industrial air pollution was associated with childhood asthma onset. The attributable risk of asthma onset in children exposed to the mean levels of air pollution, relative to the unexposed group, ranged from 4.5% (95% confidence interval [95%CI] 2.8–6.3) to 10.6% (95%CI 6.2–5.2%) for $PM_{2.5}$, and from 1.1% (95%CI 0.1–3.3%) to 8.9% (95%CI 7.1–11.1%) for SO_2.

Khreis and co-authors [14] showed that up to 38% of all annually recorded childhood asthma cases were attributable to air pollution in general, and up to 6% and 12% of all cases were attributable to traffic-related NO_x and NO_2, respectively.

In a study conducted in Israel, Greenberg et al. [6] found that for both SO_2 and NO_2, there was a significant dose-response effect of air pollution exposure on asthma severity in particular, in residential areas with high levels of SO_2

(13.3–592.7 μg/m^3) and high levels of NO_2 (27.2–43.2 μg/m^3). The risk of asthma prevalence in these areas was significantly higher than elsewhere, with odds ratio (OR) (1.409, 95%CI 1.305–1.522, $P < 0.0001$) and OR 1.440 (95%CI 1.313–1.579, $P < 0.0001$) for SO_2 and NO_2, respectively. In addition, asthma severity was better correlated with NO_2 peak concentrations rather than with average concentrations of the air pollutants. The researchers attributed the findings to differences in pathophysiological responses of the airways to exposure to different air pollutants. As the researchers argued, NO_2, which is poorly soluble in water, penetrates deep into the bronchial tree, producing its manifestations such as inflammation and increased mucus production in the lung parenchyma. In contrast, SO_2, which is highly water soluble, exerts its effects rapidly in the upper airways [7].

The aim of the present study was to examine differences in asthma frequency and severity between three major urban areas in Israel characterized by different primary sources of air pollution: predominantly traffic-related air pollution (Tel Aviv), and predominantly industrial air pollution namely, Hadera and the Haifa bay area.

PATIENTS AND METHODS

STUDY AREA

The present study covered three urban areas of Israel: Tel Aviv in central Israel, the Haifa bay area, and Hadera further north. All three areas are characterized by a high population density, and are mostly urban. As of 2015, the population in these metropolitan areas was 432,892 residents in Tel Aviv, 513,497 residents in the Haifa bay area and 88,783 residents in Hadera [15].

Tel Aviv is characterized mostly by residential and commercial areas. The largest oil refineries in the country are in the Haifa bay area, with a total production capacity of 8 million tons of oil per year and a major oil-fired power plant producing about 430 megawatt annually. In addition, there are several smaller petrochemical and agrochemical facilities. The location of the industrial complexes in the Haifa bay area, its hilly topography, and unique sea-land meteorology result in distinctive spatial patterns of air pollution in Haifa [2]. Hadera is located midway between Tel Aviv and Haifa. The largest coal-fired power plant in Israel is located north-west of the city. The station's production capacity is 2590 megawatt, which is about a quarter of the total electrical power production of the country.

All three urban areas have heavy motor traffic load, with 32% of families owning motor vehicles in the Haifa bay area, 37% in Hadera, and 64% of in Tel Aviv [16]. The city of Tel Aviv has the largest daily commuting system in the country, with about 70% of the workforce commuting to work in Tel Aviv [11]. There are 278,135 registered vehicles in Tel Aviv, or about 14% of registered vehicles in the country. However, unlike the Haifa bay area and Hadera, Tel Aviv does not have major industries. As a result, air pollution there results almost entirely from traffic pollution, while in the Haifa bay area and Hadera, both traffic and industry contribute to air pollution in the area.

STUDY POPULATION

The study population included 13,875, 16–19 year-old males, who resided in the Haifa bay area (n=7283), Tel Aviv (n=5048), or Hadera (n=1544) continuously for at least 3 years before their medical examinations at conscription to military service. All subjects were examined between 2012 and 2014 using a uniform and standardized protocol including a health-status questionnaire and information on demographic variables as a part of their recruitment process. Several variables available on the questionnaires were used in the statistical evaluations as predictors for asthma including age, socioeconomic status (SES), level of education, body mass index (BMI), country of birth, and immigration date. Women were examined according to a less comprehensive protocol for asthma; therefore, only men were included in the current study.

A study by the Israeli Bureau of Statistics indicated that, on average, Israelis tend to remain in their place of residence [17]. Moreover, about 53% of Israelis who changed their address remained in close proximity to their original residence, with another 42.3% moving to residences within the same geographic district [17]. Based on residential proximity to high schools, and the relatively low mobility of the population, we assume that exposures within this truncated time period are indicative of long-term exposure to air pollution. Migration of families from one area of the country to another prior to army enrolment is assumed to be infrequent. Therefore, we believe it is justifiable to view exposures within a one-year period as indicative of longer-term exposures to air pollution.

The study was approved by the ethics committee of the Israeli Defense Forces (#1205-2012-3).

HEALTH DATA

The medical history of each participant was obtained from the family physician using a structured protocol [17]. Whenever the record contained the diagnosis of asthma or a positive reply to any question regarding respiratory symptoms, such as wheezing, exercise-induced cough, or nocturnal cough, the recruit was referred to a pulmonologist for further evaluation. Pulmonary evaluation included physical examination and spirometry at rest. On the day of the pulmonary function test (PFT), recruits were instructed not to take any asthma medication. Prior to PFT, all subjects without overt clinical symptoms at the time of testing underwent a 6-minute treadmill test.

The treadmill test was at a speed of 5 km/hr at an inclination of 10°. During the test, subjects were breathing room air at 22°C and 50% relative humidity. PFT was performed 5 and 10 min after exercise to determine the percentage decrease in

FEV1. Following these tests, each participant was assigned an asthma severity code according to the severity of symptoms, history of asthma, lung function test results, and medications used [18,19]. Based on these criteria, asthma severity was divided into two categories:

- **Mild asthma (intermittent asthma)**: Patients with rare and mild attacks of dyspnea, normal spirometry, and normal response to exercise; and individuals who do not require regular daily medications or exhibit either mild impairment on spirometry or evidence of moderate bronchial hyperactivity.
- **Moderate–severe asthma (persistent asthma)**: Patients with a history of active asthma that required regular treatment to control symptoms, abnormal PFT, and an asthmatic response to methacholine challenge test.

ENVIRONMENTAL DATA

The environmental variables include half-hourly measurements of NO_2 and SO_2 that were conducted by the Ministry of Environmental Protection, Independent Unions of Towns, between 2012 and 2014, in the areas included in the study. Data on air pollution exposure levels at the place of residence of a certain participant were obtained from a network of 25 air quality monitoring stations and averaged to estimate annual concentrations [18].

STATISTICAL ANALYSIS

Chi-square test was used to compare asthma prevalence in different urban areas. In addition, binary logistic regression models were used to assess the association between different urban areas and the prevalence of mild and moderate/severe asthma, controlling for individual socio-demographic variables. A P value of < 0.05 was considered significant. Statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics software, version 24 (SPSS, IBM Corp, Armonk, NY, USA).

Table 1. Socio-demographic characteristics of the study cohort (N=13,875)

Demographic characteristics	N (%)
Country of birth	
Israel	12,763 (92.0%)
Other countries	1112 (7%)
Missing information	140 (1%)
Education (years)	
Less than 11 years	1004 (7.3%)
Equal or more than 11 years	12,516 (90.2%)
Missing information	355 (2.6%)
Socioeconomic status	
Average (5–7 SES cluster)	8533 (61.5%)
High (8–10 SES cluster)	5342 (38.5%)
Low (1–4 SES cluster)	–
Missing information	408 (2.9%)
Body mass index	
Normal	9451 (68.1%)
Underweight (< 17.70)	729 (5.3%)
Overweight (24.95–28.26)	1815 (13.1%)
Obese (> 28.27)	1475 (10.6%)
Missing information	408 (2.9%)
Cognitive ability	
Low (10–30)	2950 (21.3%)
Average (40–70)	8312 (59.9%)
High (80–90)	2066 (14.9%)
Missing information	547 (3.9%)

SES = socioeconomic status

Table 2. Asthma prevalence in the urban areas under study

	Asthma n (%)			
Urban area	No asthma*	Total*	Mild**	Moderate–severe**
Haifa bay area (N=7283)	6776 (93.04)	507 (6.96)	231 (3.17)	276 (3.79)
Hadera (N=1544)	1450 (93.91)	94 (6.09)	49 (3.17)	45 (2.91)
Tel Aviv (N=5048)	4606 (91.24)	442 (8.76)	268 (5.31)	174 (3.45)
Chi-square		$18.91_{df=2}$	$38.42_{df=2}$	$2.932_{df=2}$
P value		< 0.001	< 0.001	0.23
Total (N=13,875)	12,832 (92.48)	1043 (7.52)	548 (3.95)	495 (3.57)

*Percent (%) of 13,875 examinees

**Percent (%) of total asthma

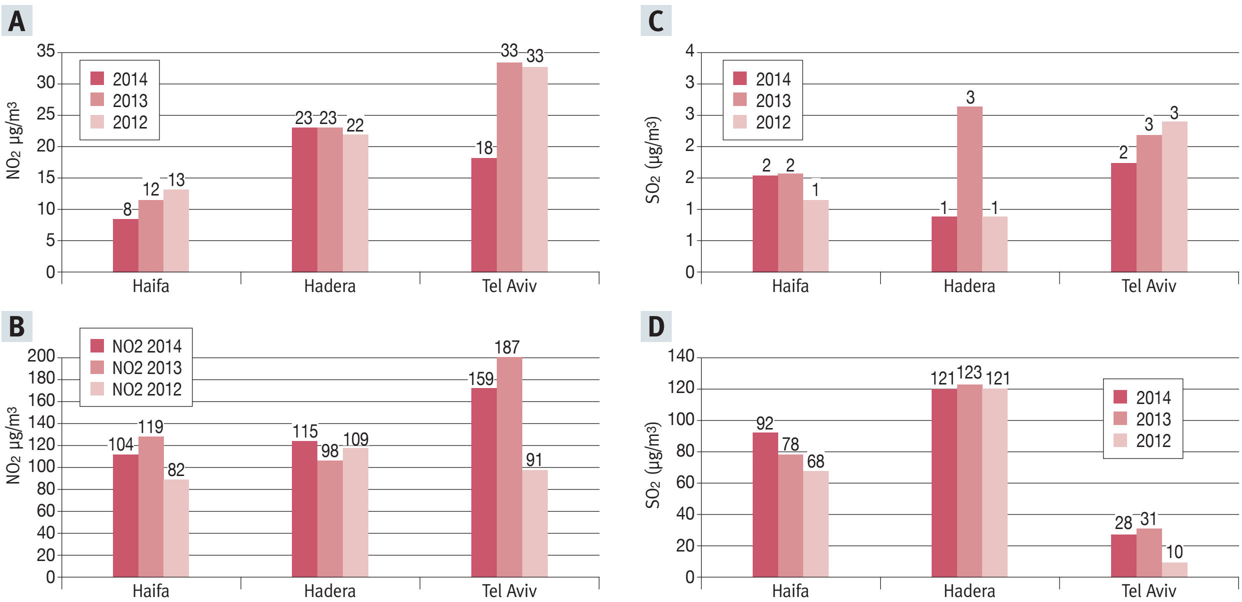
RESULTS

Of the 13,875 young male adults included in the study, 92% were born in Israel, and 90% had more than 11 years of education. Approximately two-thirds of the subjects came from average income families, a quarter were overweight or obese, and 60% had an average cognitive capacity as reflected by cognitive abilities index. Table 1 describes the socio-demographic attributes of the study cohort.

Table 2 shows asthma prevalence rates in the three urban areas under study. Asthma was diagnosed in approximately 7.5% (n=1043) of the recruits. The prevalence of overall asthma among the recruits was significantly higher in Tel Aviv (8.8%) than in the Haifa bay area (7.0%) and Hadera (6.1%) ($P < 0.001$). Similarly, the prevalence of mild asthma among the recruits was significantly higher in Tel Aviv (5.3%) than in the Haifa bay area and Hadera (3.2%) ($P < 0.001$).

Figure 1 depicts mean and maximum hourly levels of NO_2 and SO_2 for each geographic area under study. The mean air pollution levels of NO_2 were higher in Tel Aviv (28 μg/m^3) than in the Haifa bay area (11 μg/m^3) and Hadera (23 μg/m^3). The maximum hourly levels of NO_2 were higher in Tel Aviv (146 μg/m^3) compared to the Haifa bay area (102 μg/m^3), and Hadera (106 μg/m^3). The mean air pollution levels of SO_2 were higher in Tel Aviv (3 μg/m^3) compared to the Haifa bay area and Hadera (2 μg/m^3). However, the maximum hourly levels of SO_2 were higher in the Haifa bay area and Hadera (79.3 μg/m^3 and 121.6 μg/m^3, respectively) than in Tel Aviv (23 μg/m^3).

Figure 1. NO_2 and SO_2 air pollutant levels (µg/m³) in different geographic areas under study in 2012–2014; **[A]** NO_2 average concentrations, **[B]** NO_2 maximum hourly concentrations, **[C]** SO_2 average concentrations, **[D]** SO_2 maximum hourly concentrations.



NO_2 = nitrogen dioxide, SO_2 = sulfur dioxide

Table 3 shows the association between prevalence rate of asthma and geographic area by severity of the disease, using multiple logistic models, in which the effect of metropolitan location was controlled for the year of birth, country of birth, BMI, and cognitive ability of the subjects. Unlike the univariate models, which showed statistically significant differences in the total and mild asthma rates between Tel Aviv and the Haifa bay area [Table 2], no significant differences were found in the controlled regressions [Table 3]. The adjusted odds ratio for asthma risk in Tel Aviv, compared to the Haifa bay area, was 0.874. It did not reach statistical significance (95%CI 1.742–0.735). The trends for mild and moderate-severe asthma are similar [Table 3].

Table 3. The association between prevalence rate of asthma and geographic area by severity of the disease (N=13,875)

Asthma type N, %	Total asthma (N=1043, 7.52%)		Mild asthma (N=548, 3.95%)		Moderate–severe asthma (N=714, 3.57%)	
	OR (95%CI)	*P value**	OR (95%CI)	*P value**	OR (95%CI)	*P value**
Haifa bay area (N=7283), total asthma (N=507, 6.96%), mild asthma (N=231, 3.17%), moderate–severe asthma (N=276, 3.79%)	1		1		1	
Hadera (N=1544), total asthma (N=94, 6.09%), mild asthma (N=49, 3.17%), moderate–severe asthma (N=45, 2.91%)	1.31 1.742-0.735	0.250	0.962 (0.702–1.318)	0.809	0.775 (0.562–1.070)	0.121
Tel Aviv (N=5048), total asthma (N=442, 8.76%), mild asthma (N=268, 5.31%), moderate–severe asthma (N=174, 3.45%)	1.131 (0.735–1.742)	0.575	1.590 (0.836–3.026)	0.158	0.910 (0.747–1.107)	0.344

*Adjusted for year of birth, country of birth, body mass index, and cognitive abilities
95%CI = 95% confidence interval, OR = odds ratio

DISCUSSION

Among 13,740 young male adults, 9761 (7.1%) in our study cohort had a diagnosis of asthma, 4567 (3.3%) were diagnosed with mild asthma, and 5194 (3.8%) were diagnosed as moderate-severe asthma. In the present study we found that the prevalence of asthma in Tel Aviv (8.8%) is higher compared to the average asthma prevalence in the country (7.1%) [6]. Asthma prevalence in the Haifa bay area (6.96%) and in Hadera (6.09%) is lower than the country-wide average.

The present study highlights several issues related to the overall effect of air pollution on asthma prevalence in young adults. The univariate model showed higher asthma prevalence rates in Tel Aviv, (in which air pollution is predominantly related to traffic emissions) compared to the Haifa bay area and Hadera, where air pollution results from a combination of vehicular and industrial emissions. However, these differences did not reach statistical significance when the residential location was controlled for individual attributes such as SES, BMI, number of years of schooling, and cognitive abilities.

The strength of the study is that it was based on a large population-based cohort of young men who underwent a comprehensive medical examination, including spirometry at rest, exercise test (6-minute walk), and methacholine challenge test.

LIMITATIONS

Smoking habits were not considered in the analysis, as these data do not appear in the medical records. SES might be used as a proxy for smoking habits. Several studies reported a significant correlation between SES and smoking habits [2,20,21] indicating that low income might be a risk factor for teenage smoking. A large-scale nationwide study showed that low SES and low educational level were significantly associated with smoking among men [22]. Similarly, due to lack of family history on asthma, we were not able to evaluate possible confounding by childhood asthma. However, this factor would affect all three regions in a similar way.

CONCLUSIONS

Our findings indicate that exposure both to industrial- and traffic-related air pollution have a detrimental effect on respiratory health of young males and are positively associated with asthma prevalence. More refined methods are needed to determine the relative effect of different air pollutants.

Correspondence
Dr. N. Greenberg
School of Public Health, University of Haifa, Haifa 31905, Israel
email: neches@gmail.com

References

1. Bibi H, Shoseyov D, Feigenbaum D, et al. Comparison of positive allergy skin tests among asthmatic children from rural and urban areas living within small geographic area. *Ann Allergy Asthma Immunol* 2002; 88: 416-20.
2. Portnov BA, Reiser B, Karkabi K, Cohen-Kastel O, Dubnov J. High prevalence of childhood asthma in Northern Israel is linked to air pollution by particulate matter: evidence from GIS analysis and Bayesian model averaging. *Int J Environ Health Res* 2011; 22: 249-69.
3. Yogev-Baggio T, Bibi H Dubnov J, Or-Hen K, Carel R, Portnov AB. Who is affected more by air pollution sick or healthy? Some evidence from a health survey of schoolchildren living in the vicinity of a coal-fired power plant in Northern Israel. *Health Place* 2010; 16 (2): 399-408.
4. Greenberg N, Carel R, Portnov BA. Air pollution and respiratory morbidity in Israel: a review of accumulated empiric evidence. *IMAJ* 2015; 17: 445-50.
5. Ebenstein A, Frank E, Reingewertz Y. Particulate matter concentrations, sandstorms and respiratory hospital admissions in Israel. *IMAJ* 2015; 17: 628-31.
6. Greenberg N, Carel RS, Derazne E, et al. Different effects of long-term exposures to SO_2 and NO_2 air pollutants on asthma severity in young adults. *J Toxicol Environ Health A* 2016; 79 (8): 342-51.
7. Greenberg N, Carel RS, Derazne E, Tiktinsky A, Tzur D, Portnov BA. Modeling long-term effects attributed to nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) exposure on asthma morbidity in a nationwide cohort in Israel. *J Toxicol Environ Health A* 2017; 80 (6): 326-37.
8. Bergstra AD, Brunekreef B, Burdorf A. The effect of industry-related air pollution on lung function and respiratory symptoms in school children. *Environ Health* 2018; 17: 30.
9. World Health Organization (WHO). Review of evidence on health aspects of air pollution 2013 [Available from http://www.euro.who.int/data/assets/pdf_file/0004/193108/REVIHAAP-final-technical-report-final-version.pdf]. [Accessed 23 April 2015].
10. Israel Central Bureau of Statistics. Motor Vehicles in Israel in 2016. 2018 [Available from http://www.cbs.gov.il/www/publications/teunot/616/memtzaim_616.pdf]. [Accessed 02 April 2018]. [Hebrew].
11. Israel Central Bureau of Statistics. Residents. [Available from https://www.cbs.gov.il/he/settlements/Pages/default.aspx?]. [Accessed 11 February 2019]. [Hebrew].
12. Greenwald R, Sarnat SE, Raysoni AU, et al. Associations between source-indicative pollution metrics and increases in pulmonary inflammation and reduced lung function in a panel of asthmatic children. *Air Qual Atmos Health* 2013; 6: 487-99.
13. Buteau S, Doucetac M, Tétreault LF, et al. A population-based birth cohort study of the association between childhood-onset asthma and exposure to industrial air pollutant emissions. *Environ Int* 2018; 121 (2): 23-30.
14. Khreis H, de Hoog K, Nieuwenhuijsen MJ. Full-chain health impact assessment of traffic-related air pollution and childhood asthma. *Environ Int* 2018; 114: 365-75.
15. Israel Central Bureau of Statistics. Demographic situation in Israel, 2008. 2019 [https://www.cbs.gov.il/he/settlements/Pages/default.aspx?mode=Yeshuv] [Accessed 28 June 2019]. [Hebrew].
16. Israel Central Bureau of Statistics. Motor Vehicles Registered in Cities (Table 8). Jerusalem, Israel 2015. Publication No. 1688. [Available from https://www.cbs.gov.il/he/publications/Pages/2017/]. [Accessed 30 October 2019].
17. Farfel A, Tirosh A, Derazne E, Garty BZ, Afek A. Association between socioeconomic status and the prevalence of asthma. *Ann Allergy Asthma Immunol* 2010; 104: 490-5.
18. Israel Ministry of Environmental Protection. 2015. Israel air monitoring network laboratories. [Available from http://www.sviva.gov.il/English/env_topics/AirQuality/Pages/NationalAirMonitoringNetwork.aspx?] [Accessed 30 October 2019].
19. GINA Report. 2016. The global strategy for asthma management and prevention: Global Initiative for Asthma (GINA) [Available from https://ginasthma.org/gina-reports/] [Accessed 30 October 2019].
20. Dubnov J, Barchana M, Rishpon S, et al. Estimating the effect of air pollution from a coal-fired power station on the development of children's pulmonary function. *Environ Res* 2007; 103: 87-98.
21. Hanson MD, Chen E. Socioeconomic status and health behaviors in adolescence: a review of the literature. *J Behav Med* 2007; 30: 263-85.
22. Kalter-Leibovici O, Chetrit A, Avni S, Averbuch E, Novikov I, Daoud N. Social characteristics associated with disparities in smoking rates in Israel. *Isr J Health Policy Res* 2016; 5: 36.

"How can it be, in a world where half the things a man knows at 20 are no longer true at 40 and half the things he knows at 40 hadn't been discovered when he was 20?"

Arthur C. Clarke (born 1917), British science fiction author, inventor, and futurist

"The bicycle is the most civilized conveyance known to man. Other forms of transport grow daily more nightmarish. Only the bicycle remains pure in heart"

Iris Murdoch (1919–1999), British novelist and philosopher best known for her novels about good and evil, sexual relationships, morality, and the power of the unconscious