HUMAN EXPOSURE TO PERSISTENT ORGANIC POLLUTANLS, PLASTICS ASSOCIATED CHEMICALS AND METALS IN RELATION TO DIEATARY PATTERN IN A COHORT OF ELDERLY MEN AND WOMEN FROM SWEDEN

Samira Salihovic [1], Erik Lampa [2], Erika Ax [3], Lars Lind [4], P. Monica Lind [2], Per Sjögren [3], Bert van Bavel [1]

[1] MTM Research Center, School of Science and Technology, Örebro University, Sweden[2] Department of Medical Sciences, Occupational and Environmental Medicine, Akademiska sjukhuset, Uppsala University, Sweden
[3] Department of Medical Sciences, Clinical Nutrition and Metabolism, Akademiska sjukhuset, Uppsala University, Sweden[4] Department of Medical Sciences, Acute and Internal Medicine, Akademiska sjukhuset, Uppsala University, Sweden

Introduction

Persistent Organic Pollutants (POPs) are a group of toxic chemicals that originate from various anthropogenic sources. Although, the production, use and disposal has been banned and restricted in many countries, they are still wide spread and can be found in human blood, milk, and adipose tissue in populations around the world. In addition to the POPs, the industrial use and production of metals, such as cadmium, lead and mercury has been, and still is, a problem in many industrialized countries. More recently, another group of environmental pollutants with suspected negative health effects have emerged. Bisphenol A and the phthalates are chemicals typically used in the production of plastics. All of these environmental pollutants have been reported to cause negative health effects in humans and a number of factors have been reported to influence the exposure of an individual. Ingestion of contaminated food is, so far, considered to be the main source of exposure to the majority of such pollutants. Numerous studies have shown that foods with a high fat content such as fish, meat, and dairy products are of particular concern. The dietary pattern, in terms of product and quantity, might play a significant role in the overall exposure in an individual. Therefore, biomonitoring of levels, as well as identifying possible sources of exposure, is important when estimating possible health risks in the general population.

In the Prospective Investigation of the Vasculature in Uppsala Seniors (PIVUS) we performed a characterization of the individual dietary pattern in 846 out of 1016 subjects. Analyses of the 1016 blood samples were performed on a broad range of POPs, metals, and plastic associated chemicals. In short, the aim of the study was to investigate whether the overall dietary pattern was associated with the concentrations of 37 different environmental pollutants, including polychlorinated biphenyls (PCBs), organochlorine (OC) pesticides, polybrominated diphenylethers (PBDEs), dioxins, metals as well as bisphenol A (BPA) and 10 phthalate metabolites.

Materials and methods

Study Population

Eligible for the study were all subjects aged 70 living in the community of Uppsala, Sweden. The subjects were chosen from the register of community living and invited in a randomized order. The individuals received an invitation by letter within 2 months of their 70th birthday. Of the 2025 invited, 1016 (50.2 % females) subjects participated, resulting in a participation rate of 50.1 percent. Dietary data was collected from 7-day food records and dietary patterns where assessed with established methods, determining adherence to a Carbohydrate-Restricted diet (CR), a Mediterranean-like diet (MDS), and a WHO-recommended diet (by using the Healthy Diet Indicator, HDI). The study was approved by the Ethics Committee of the University of Uppsala and the participants gave informed consent. Further information on the PIVUS cohort has been reported elsewhere [1].

Blood Sampling

All subjects were sampled in the morning after an overnight fast. No medication or smoking was allowed after midnight. During the sampling, the subjects were supine in a quiet room maintained at a constant temperature. After sampling, blood serum/plasma were collected and placed in freezers (at -20 °C) until analysis.

Extraction and analysis

POPs

Blood plasma samples were collected from 1006 (50.2% female) subjects. Each plasma sample was prepared based on the method employed by Sandau et al [2]. A volume of 0.5 mL of plasma was sonicated with 1 mL of formic acid. Solid phase extraction was performed by loading the sample on an Oasis® HLB SPE (Waters, Milford, MA, USA) single use cartridge (6cm^3/150mg), which was previously conditioned. After extraction of the analytes, the samples were further cleaned up using a small activated silica gel column (2mL, 1.5g). The final extract was reconstituted in tetradecane and injected on a HRGC/HRMS system.

Metals

Whole blood was used for the determination of 11 metals. The analysis was performed using inductively coupled plasma-sector field mass spectrometry, ICP-SFMS, after microwave assisted digestion with nitric acid according to a method accredited for 10 of the 11 metal elements tested with Al being unaccredited [3].

Phthalates and bisphenol A

Serum was used for the determination of following target analytes: Bisphenol A (BPA) and ten phthalate metabolites (Mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP), Mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP), Mono-(2-ethylhexyl) phthalate (MEHP), Monobenzyl phthalate (MBZP), Monocyclohexyl phthalate (MCHP), Monoethyl phthalate (MEP), Monoisobutyl phthalate (MIBP), Monoisononyl phthalate (MINP), Monomethyl phthalate (MMP), Mono-n-octyl phthalate (MOP)) at ALS Canada following the standard procedures presented by the U.S. Centers for Disease Control and Prevention [4,5]. Analysis was performed on an API 4000 LC/MS/MS system.

Quality Control

The extraction methods employed were successfully validated in terms of recovery, precision and reproducibility and applied to all samples. Quality control reference samples and procedural blank samples were incorporated each batch of samples and treated as a real sample. The recoveries of the internal standards were in general satisfactory and ranging from 60-110%.

Data analysis

Multivariate regression analysis was used to evaluate possible associations between the blood concentrations of environmental pollutants in relation to the dietary patterns.

Results and discussion

A wide range of selected environmental pollutants with varying concentrations were observed in the cohort. The detection rates for all compounds were, in general, relatively high, ranging from 75% and higher (data not shown). The higher detection rates, as well as the wide ranges of concentrations detected in this elderly cohort, demonstrate the long-term accumulation and persistence of these compounds.

Table 1. Multivariate Linear Regression Analyses of Dietary Pattern-determinants on POPs, Plastics Associated Chemicals and Metals.

Analytes	Abbrev	*N*	Dietary pattern		
			Carbohydrate Restricted (CR)	Mediterranean (MDS)	Healthy diet indicator (HDI)
			β	*β*	*β*
Persistent Organic Pollutants	POPs				
Polychlorinated biphenyl	PCB				
2,4,4',5-tetrachlorobiphenyl	PCB74	597	0.09**	0.08*	0.03
2,2',4,4',5-pentachlorobiphenyl	PCB99	597	0.06	0.08*	0.04
2,3,3',4,4'-pentachlorobiphenyl	PCB105	597	0.10**	0.16***	-0.03
2,3',4,4',5-pentachlorobiphenyl	PCB118	597	0.09**	0.13***	-0.03
3,3',4,4',5-pentachlorobiphenyl	PCB126	597	0.06	0.13*	-0.14
2,2',3,4,4',5'-hexachlorobiphenyl	PCB138	597	0.06*	0.07*	0.00
2,2',4,4',5,5'-hexachlorobiphenyl	PCB153	597	0.06*	0.07**	-0.02
2,3,3',4,4',5-hexachlorobiphenyl	PCB156	597	0.02	0.07**	-0.05
2,3,3',4,4',5'-hexachlorobiphenyl	PCB157	597	0.02	0.07*	-0.05
3,3',4,4',5,5'-hexachlorobiphenyl	PCB169	597	0.00	0.05	-0.10*
2,2',3,3',4,4',5-heptachlorobiphenyl	PCB170	597	0.03	0.05*	-0.05
2,2',3,4,4',5,5'-heptachlorobiphenyl	PCB180	597	0.03	0.06*	-0.04
2,3,3',4,4',5,5'-heptachlorobiphenyl	PCB189	597	0.01	0.08	-0.09
2,2',3,3',4,4',5,5'-octachlorobiphenyl	PCB194	597	0.02	0.12**	-0.01
2,2',3,3',4,4',5,5',6-nonachlorobipehnyl	PCB206	597	0.00	0.05*	-0.03
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl	PCB209	597	0.00	0.06*	-0.02
Polychlorinated dibenzo-*p*-dioxins	PCDD				
Octachlorodibenzo-p-dioxin	OCDD	597	-0.01	0.06	-0.14*
Organochlorine pesticide	OC pesticide				
Hexachlorobenzene	HCB	597	0.07**	0.05	-0.05
Trans-Nonachlor		597	0.10**	0.10**	0.03
2,2-Bis(4-chlorophenyl)-1,1-dichloroethene	p,p'-DDE	597	0.18**	0.04	0.09
Poly Brominated Diphenyl Ether	PBDE				
2,2',4,4'-tetrabromodiphenyl ether	PBDE #47	597	-0.02	0.13**	-0.11
Plastics associated chemicals					
Bisphenol-A	BPA	597	-0.07	0.03	0.00
Mono-methyl phthalate	MMP	597	-0.09	-0.03	0.07
Mono-ethyl phthalate	MEP	597	-0.06	-0.03	0.03
Mono-2-ethylhexyl phthalate	MEHP	597	0.12	0.02	0.12
Mono-isobutyl phthalate	MIBP	597	0.04	0.02	-0.06
Metals					
Aluminum	Al	597	-0.03	-0.02	-0.03
Cadmium	Cd	597	-0.02	0.09**	-0.10*
Cobalt	Co	597	-0.04	0.04	-0.04
Chromium	Cr	597	0.00	0.00	-0.05
Copper	Cu	597	0.01	0.00	0.00
Mercury	Hg	597	0.07	0.25***	-0.04
Manganese	Mn	597	-0.01	0.02	-0.01
Molybdenum	Mo	597	0.01	-0.03	0.04
Nickel	Ni	597	0.07	-0.03	0.11
Lead	Pb	597	0.00	0.09**	-0.20***
Zn	Zn	597	0.00	0.00	-0.01

Note: * = $p < .05$; ** = $p < .01$; *** = $p < .001$

However, some of the compounds such as, *cis*-chlordane and *trans*-chlordane were below the detection limit in the majority of the samples and were therefore excluded in the regression analysis. Only the four phthalate metabolites with detectable levels in almost all subjects were used in the statistical analysis. The fact that some subjects showed undetectable levels rules out a general contamination of these compounds. For the remaining phthalate metabolites, no detectable levels were seen in the majority of the subjects, which further rules out contamination regarding these metabolites.

In total, reliable dietary data was obtained from 639 subjects (51% women, 49% men) from the PIVUS cohort and data from 597 subjects was used in the statistical analyses. Significant differences between dietary patterns and overall blood concentrations of environmental pollutants were observed and are given in Table 1. Dietary pattern-specific analyses revealed the CR diet to be positively associated with five PCB congeners and with three pesticides (HCB, *trans*-nonchlor and p, p'-DDE). The MDS was positively associated with all but two PCBs tested, *trans*-nonachlor, BDE47 as well as higher levels of Cd, Pb, and Hg. Conversely, HDI was negatively associated with one PCB, OCDD as well as Cd and Pb.

Conclusion

This unique study on various environmental pollutants in elderly Swedish men and women indicates a higher body burden of pollutants in individuals that adhere to either a Mediterranean or a carbohydrate restricted diet. However, we found the WHO-recommended healthy indicator diet to be positively associated with lower body burdens of the same pollutants. Consequently, these results indicate that following the recommendations made by the WHO might significantly reduce the dietary exposure of many of the environmental pollutants studied. Although these results were observed, further investigations are required to be able to determine the specific origin of the pollutants, as well as the possible health consequences in the cohort.

Acknowledgements

This study was supported by the Swedish Research Council (VR) and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS). We greatly acknowledge Helen Björnfoth, Jessika Hagberg and Lisa Mattioli for their technical assistance. ÅForsk (Ångpanneföreningen's Foundation for Research and Development) is acknowledged for travel grants.

References

[1] L. Lind, N. Fors, J. Hall, K. Marttala, A. Stenborg, Journal of Hypertension 24 (2006) 1075.

[2] C.D. Sandau, A. Sjodin, M.D. Davis, J.R. Barr, V.L. Maggio, A.L. Waterman, K.E. Preston, J.L. Preau, D.B. Barr, L.L. Needham, D.G. Patterson, Analytical Chemistry 75 (2003) 71.

[3] I. Rodushkin, F. Odman, R. Olofsson, M.D. Axelsson, Journal of Analytical Atomic Spectrometry 15 (2000) 937.

[4] M.J. Silva, D.B. Barr, J.A. Reidy, K. Kato, N.A. Malek, C.C. Hodge, D. Hurtz, A.M. Calafat, L.L. Needham, J.W. Brock, Archives of Toxicology 77 (2003) 561.

[5] A.M. Calafat, Z. Kuklenyik, J.A. Reidy, S.P. Caudill, J. Ekong, L.L. Needham, Environmental Health Perspectives 113 (2005) 391.