Concentrations and congener profiles of non-dioxin-like polychlorinated biphenyls in blood collected from 195 pregnant women in Sapporo City, Japan

Todaka T[1], Hori T[2], Hirakawa H[2], Kajiwara J[2], Yasutake K[2], Onozuka D[2], Washino N[3], Konishi K[3], Sasaki S[3], Yoshioka E[3], Yuasa M[3], Kishi R[3], Iida T[4], Furue M[1]

[1]Department of Dermatology, Graduate School of Medical Sciences, Kyushu University, Maidashi 3-1-1, Higashi-ku, Fukuoka 812-8582, Japan; [2]Fukuoka Institute of Health and Environmental Sciences, Mukaizano 39, Dazaifu-shi, Fukuoka 818-0135, Japan; [3]Department of Public Health, Hokkaido University Graduate School of Medicine, Kita 15, Nishi 5, Kita-ku, Sapporo, 060-8638, Japan; [4]Kitakyushu Life Science Center, 1-4 Nakabarushinmati, Tobata-ku, Kitakyushu-city, 804-0003, Japan

Introduction

Polychlorinated biphenyls (PCBs) are ubiquitous highly toxic compounds distributed throughout the environment. A total of 209 PCB congeners can be produced depending on the number of chlorine atoms and their position on the biphenyl structure. When non-dioxin-like PCBs are released into the environment, these PCBs accumulate in the human body through ingested food. Among these 209 PCB congeners, 12 PCBs that have a planar structure proposed as dioxin-like PCBs are assumed to possess dioxin-like PCBs toxicities. However, the toxicities have been suggested not only with dioxin-like PCBs but also with non-dioxin-like PCBs, and can be viewed as non-dioxin-like PCBs toxicities that are not mediated by the arylhydrocarbon receptor system. We have previously reported that PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs in the maternal body are transferred from the mother to her fetus via the placenta. Studies in humans and other vertebrates have demonstrated that pre- and/or postnatal exposure to non-dioxin-like PCBs may elicit many adverse health effects such as neurodevelopmental deficits, thyroxin deficiency, and reproductive effects. Therefore, in order to elucidate the influence of non-dioxin-like PCBs on the health of fetuses and infants, survey studies of the transplacental and lactational exposures of these PCB congeners are necessary. Although exposure studies regarding non-dioxin-like PCBs in human blood have been reported for the last several decades, published data showing the full congener-specific concentrations of non-dioxin-like PCBs are limited and less information is available regarding exposure of pregnant women to non-dioxin-like PCBs in Japan. In the last decade, advances in analytic methods for quantification of PCBs have resulted in widespread availability of congener-specific analysis procedures[1].

In this study, we carried out the first survey of each congener concentrations of non-dioxin-like PCBs in blood samples collected between July 2002 and July 2004 from 195 pregnant women living in Sapporo City of Hokkaido Prefecture, Japan. The objectives of our primary study were: (1) to determine the current levels of non-dioxin-like PCBs in the blood of pregnant woman in Sapporo City, Japan, and (2) to examine the relationship between concentrations of non-dioxin-like PCBs in the blood and the delivery time or age of the mother.

Materials and Methods

Hokkaido Prefecture is located in the northern Japanese archipelago that extends from north to south, and its area accounts for one-fifth of the nation's total land area. Hokkaido Prefecture consists of a total of 212 characteristic municipalities, including its capital, Sapporo City, which has a population of 1.8 million. All the subjects participating in this study were native Japanese and were residents of Sapporo City or the surrounding area. The blood samples were collected between July 2002 and July 2004 from 195 pregnant women, from whom informed consent was obtained. The blood samples were collected from the maternal peripheral vein after the second trimester during their last pregnancy. Among the 195 pregnant women, 101 mothers were primipara and 94 mothers were multipara. The ages of the primiparous and the multiparous mothers were within 18-40 years (mean: 28.8 years, median: 28.0 years) and 20-47 years (mean: 32.3 years, median: 33.0 years), respectively. After collection, the blood samples were stored at 4°C until analyses for congener concentrations of non-dioxin-like PCBs. The extraction of non-dioxin-like PCBs from the blood samples was performed using a previously reported method[2,3] Concentrations of each congener of the non-dioxin-like PCBs were measured using high-resolution gas chromatography/high-resolution mass spectrometry[4]. To estimate the total concentration of non-dioxin-like PCBs congeners, we introduced ND (less than the detection limit) values to half values of the detection limit. The statistical analysis was conducted using Mann-Whitney's *U* test and Spearman's rank correlation in the software program from SAS Institute (SAS Inc.). All statistical testing was 2-side with a significance level of 5%.

Results and discussion

The 209 PCB congeners consist of 12 dioxin-like PCBs and 197 non-dioxin-like PCBs. Of these 197 non-dioxin-like PCB congeners, 58 were identified in the blood of pregnant women in the present study (Table 1). We compared the congener patterns of non-dioxin-like PCBs in the present study with those from 24 healthy Japanese volunteers (12 men and 12 women; age range 25-46 years) that had previously been reported in Japan[5]. Among 85 non-dioxin-like PCB congeners that were measured in the blood, as previously reported, 56 of these congeners were commonly detected in the blood of primiparous and multiparous mothers in the present study. The total concentrations of the 56 congeners contributed approximately 96% of the total concentrations of 85 non-dioxin-like PCB congeners.

The sum of the ratios of the concentrations of hexaCBs and heptaCBs to the total concentrations of non-dioxin-like PCB congeners in the blood of primiparous and multiparous mothers were 78.5 and 77.7%, respectively (Table 1). The hexaCBs ratios in the blood of primiparous and multiparous mothers were 45.4 and 44.7%, respectively, which was particularly high compared with those of other congeners. HexaCB-153 among hexaCBs congeners, the most abundant congener in the blood of primiparous and multiparous mothers, contributed approximately 22.0 and 21.8% to the total concentrations of non-dioxin-like PCB congeners, respectively. Among the non-dioxin-like PCB congeners measured in the present study, hexaCB-138, heptaCB-170, heptaCB-180, and heptaCB-182/heptaCB-187 also showed high ratios to total concentrations of these PCBs congeners in the blood of primiparous and multiparous mothers. The results obtained in the present study are similar to those that have been recently reported in Japan[5]. The total concentrations of these five congeners containing hexaCB-153 in primiparous and multiparous mothers contributed approximately 61.5 and 60.9% of the total concentrations of non-dioxin-like PCB congeners, respectively. Other PCB congeners contributed less than 5% of total concentrations of non-dioxin-like PCB congeners.

In a previous study, we measured the concentrations of PCDDs, PCDFs, and dioxin-like PCBs in the blood of 195 pregnant women in Sapporo City[6]. The results have indicated that the levels of PCDDs, PCDFs, and dioxin-like PCBs in maternal blood have decreased compared to past levels in Japan. The non-dioxin-like PCBs levels obtained in the present study were lower than those of the subjects in other domestic areas, in which the subject age was similar to that in this study. These results suggest that the levels of environmental pollution and human exposure to PCDDs, PCDFs, dioxin-like-PCBs, and non-dioxin like PCBs in Sapporo City are relatively low.

The concentrations of each congener of non-dioxin-like PCBs in the blood of primiparous mothers were found to be notably higher than those of multiparous mothers (Table 1). However, the concentrations of each congener of octaCBs, nonaCBs, and decaCB-209 of multiparous mothers tended to be slightly higher than those of primiparous mothers. The arithmetic mean total concentrations of non-dioxin-like PCB congeners of primiparous and multiparous mothers in Sapporo City were 42.2-329.3 (mean: 114.5, median: 98.6) and 31.5-258.0 (mean: 100.3, median: 91.4) ng g^{-1} lipid, respectively, indicating that the total concentrations of these PCB congeners of primiparous mothers tended to be slightly higher compared those of multiparous mothers (p=0.135). The relative contribution ratios of the concentrations of triCBs, tetraCBs, pentaCBs, hexaCBs, and heptaCBs to the total concentrations of non-dioxin-like PCB congeners for primiparous and multiparous mothers were 1.6, 6.2, 6.8, 45.4, and 33.2%, respectively, and 1.5, 5.8, 6.5, 44.7, and 33.0%, respectively, and the ratios were almost the same. These findings suggest that non-dioxin-like PCBs had accumulated in the maternal body that would be eliminated by delivery, while the octaCBs, nonaCBs, and decaCB-209 tended to not be eliminated by delivery, and that the ratios of the concentrations of triCBs, tetraCBs, pentaCBs, hexaCBs, and heptaCBs to the total concentrations of non-dioxin-like PCB congeners in maternal blood were almost the same as those obtained after delivery.

Table 1. Concentrations of non-dioxin-like PCBs in the blood of 195 pregnant women collected in Sapporo City, Japan

	Concentration (pg g^{-1} lipid)										
	Primipara (n=101)					Multipara (n=94)					
IUPAC #	Mean	Median	SD	Min.	Max.	Mean	Median	SD	Min.	Max.	*p* values
TriCB-28	1357	1267	660	5	3603	1177	1090	561	5	3074	0.050
TriCB-29	14	5	24	5	129	11	5	19	5	123	0.262
TriCB-37	464	5	1770	5	16060	336	5	1078	5	6185	0.465
TetraCB-44	363	338	197	5	1238	325	319	238	5	1447	0.139
TetraCBs-47/48	441	420	279	5	1512	390	381	286	5	1431	0.163
TetraCB-49	244	233	133	5	890	244	220	168	5	924	0.696
TetraCBs-52/69	822	749	645	5	3418	618	623	546	5	2483	0.029
TetraCBs-56/60	317	274	204	32	1036	280	255	155	5	974	0.384
TetraCB-63	62	52	42	5	211	56	49	41	5	351	0.230
TetraCB-66	761	625	494	63	2435	695	615	405	88	2066	0.480
TetraCB-70	162	170	113	5	591	160	154	163	5	1204	0.292
TetraCB-71	94	74	78	5	401	114	97	107	5	708	0.272
TetraCB-74	3821	3199	2425	1275	13798	2957	2786	1359	784	6415	0.013
PentaCB-85	123	99	118	5	1083	114	102	60	5	340	0.855
PentaCB-87	350	302	234	62	2071	314	304	148	5	759	0.512
PentaCB-92	363	279	274	5	1681	296	244	198	5	898	0.129
PentaCBs-93/95/98	443	438	285	5	1762	466	451	259	20	1220	0.415
PentaCB-99	4657	4208	2376	1214	14686	3814	3534	1808	1011	8779	0.013
PentaCB-101	830	729	531	91	3433	748	657	413	41	2014	0.305
PentaCBs-107/108	389	330	284	70	1676	320	280	192	55	856	0.149
PentaCB-110	219	182	210	5	1524	203	190	160	5	700	0.908
PentaCB-117	367	302	243	113	1453	281	262	133	11	712	0.020
HexaCB-128	467	370	498	37	4766	409	372	221	60	1130	0.764
HexaCB-130	768	641	501	5	2806	596	542	370	5	1394	0.024
HexaCB-132	108	105	82	5	398	112	100	97	5	452	0.990
HexaCB-134	12	5	14	5	68	10	5	11	5	49	0.326
HexaCB-135	192	177	117	5	578	180	143	120	5	633	0.324
HexaCB-137	869	770	435	262	2510	769	727	348	217	1957	0.138
HexaCB-138	14113	12665	7466	4992	44627	12066	11187	5916	3214	31747	0.045
HexaCB-139	260	237	193	5	881	273	229	221	5	1009	0.955
HexaCB-141	122	110	102	5	537	124	92	109	5	514	0.927
HexaCB-146	2329	2021	2690	5	13645	2299	1911	2348	5	10645	0.878
HexaCB-147	151	132	101	5	583	127	114	84	5	388	0.076
HexaCB-151	489	382	377	98	2605	421	326	295	5	1386	0.180
HexaCB-153	25239	22935	13489	8848	77686	21850	19070	11799	5721	62670	0.050
HexaCBs-163/164	5507	4609	3462	1772	19612	4740	3955	2781	1036	12897	0.120
HexaCB-165	1341	5	1948	5	8699	878	5	1470	5	5067	0.123
HeptaCB-170	6159	5025	4110	1545	24488	5264	4681	2738	1503	14140	0.323
HeptaCB-172	938	739	660	238	3877	823	724	456	199	2186	0.511
HeptaCB-177	1905	1486	1315	566	7121	1567	1370	869	349	4290	0.116
HeptaCB-178	1645	1295	1143	364	7130	1440	1151	976	322	5338	0.174
HeptaCB-179	85	66	83	5	658	80	67	56	5	283	0.832
HeptaCB-180	17413	13570	12100	3763	75056	15498	13772	8731	4165	45142	0.563
HeptaCB-181	29	24	26	5	123	25	24	19	5	78	0.728
HeptaCBs-182/187	7557	5847	5594	1857	36848	6463	5347	4050	1638	21413	0.226
HeptaCB-183	2029	1593	1520	578	11206	1778	1577	1019	409	5109	0.363
HeptaCB-191	218	182	145	5	744	179	160	102	5	500	0.116
OctaCB-194	1733	1488	1008	475	5781	1863	1654	1083	480	7090	0.342
OctaCB-195	436	370	261	83	1556	441	390	250	104	1444	0.711
OctaCBs-196/203	1743	1411	1078	456	6436	1809	1508	1129	5	7503	0.514
OctaCBs-198/201	2078	1797	1283	625	7572	2140	1856	1460	483	10610	0.839
OctaCB-200	103	86	70	5	475	105	93	63	17	322	0.604
OctaCB-202	489	409	290	86	1851	503	418	349	98	2087	0.809
OctaCB-205	85	72	45	5	249	83	76	43	5	261	0.894
NonaCB-206	524	453	291	162	1964	605	513	371	100	2278	0.106
NonaCB-207	105	89	59	5	295	106	92	61	5	355	0.736
NonaCB-208	204	160	126	62	728	222	189	169	44	1045	0.554
DecaCB-209	439	377	200	154	1035	523	439	380	181	3300	0.124
Total TriCBs	1835	1439	1895	317	17655	1523	1193	1187	15	7871	0.069
Total TetraCBs	7087	6239	3507	2340	23780	5838	5791	2318	1952	12894	0.021
Total PentaCBs	7742	7106	3933	1903	25548	6555	6074	2784	1424	13960	0.058
Total HexaCBs	51967	47104	27235	19278	165276	44855	39627	22760	12612	118206	0.052
Total HeptaCBs	37978	29844	26241	10651	167252	33118	29585	18606	9096	96561	0.362
Total OctaCBs	6667	5680	3933	2016	22738	6944	6014	4255	1542	29270	0.594
Total NonaCBs	834	703	457	264	2889	933	783	585	204	3506	0.230
Total DecaCB	439	377	200	154	1035	523	439	380	181	3300	0.124
Total PCBs	114549	98556	61059	42189	329326	100289	91353	48226	31458	257960	0.135

CB: chlorinated biphenyl; SD: standard deviation.

A statistical examination of the relationship between the total concentrations of non-dioxin-like PCB congeners in blood and maternal age indicated significant correlations between the total concentrations of these PCB congeners and the age of primiparae (ρ=0.547, p<0.001). We also observed significant correlations between the total concentrations of these PCBs congeners and the age of multiparae (ρ=0.467, p<0.001).

We estimated the correlations between the concentrations of each congener of non-dioxin-like PCBs and the total concentrations of these PCB congeners. The result of a comparison of the correlation coefficient between both the concentrations indicated that the total concentrations of there PCB congeners in the blood of primiparae (correlation coefficient ρ=0.973, p<0.001) and multiparae (correlation coefficient ρ=0.977, p<0.001) highly correlated with the hexaCB-153 concentrations, which suggested that hexaCB-153 could be an indicator for total non-dioxin-like PCB concentrations in the blood of pregnant women.

Acknowledgment

This work was supported in part by a Grant-in-Aid for scientific research from the Ministry of Health Labour and Welfare, Japan.

Reference

1. Matsumura T, Tsurukawa M, Nakano T, Ezaki T, Ohashi M. J. Environ. Chem. 2002; 12, 855
2. Todaka T, Hirakawa H, Tobiishi K, Iida T. Fukuoka Igaku Zasshi 2003; 94: 148
3. Todaka T, Hirakawa H, Hori T, Tobiishi K, Iida T. J. Dermatol.Sci. Suppl. 2005; 1, 21
4. Hori T, Tobiishi K, Ashizuka Y, Nakagawa R, Todaka T, Hirakawa H, Iida T. Fukuoka Igaku Zasshi 2005; 96(5): 220
5. Hirai T, Fujimine Y, Watanabe S, Nakano T. Geochem. Health 2005; 27, 65
6. Todaka T, Hirakawa H, Kajiwara J, Hori T, Tobiishi K, Onozuka D, Kato S, Sasaki S, Nakajima S, Saijo Y, Sata F, Kishi R, Iida T, Furue M. Chemosphere 2005; 69, 1228