P-3a-195

Reference Man Models Based on Normal Data from Human Populations

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INTRODUCTION

Physical, physiological and metabolic parameters of the human body are the very basic data for internal dosimetry (1,2). Compilation of such data for Asian populations has been of great significance because of potential use of the nuclear power in the region that has a major contribution to the world population of ca.58%
while such data were scarcely found. In the revision of ICRP Reference Man by the Task Group, characteristics of the human body of non-European populations, that were begun to be reported, attracted a considerable interest as well as those of the European populations of different sexes and ages after the Chernobyl accident (3). The IAEA-RCA Co-ordinated Research Programme (CRP) on Compilation of Anatomical, Physiological and Metabolic Characteristics for a Reference Asian Man was therefore endorsed (4,5). In fact, differences are reported for race, body sizes and habit, i.e. pattern of food consumption between the Asian and European populations (4-7). Lately, anatomical data for Asians appear to contribute to the discussion on those for European populations and ICRP seems to suggest unanimous use of its Reference Man for radiation protection worldwide.

Reference man models for adults and 15, 10, 5, 1, 0 year-old males and females of Asian populations were previously developed for use in internal and external dosimetry. Being based on the concept of ICRP Reference Man (Publication 23), the reference values were derived from the normal organ mass data for Japanese and statistical data on the physique and nutrition of Japanese and Chinese. Also incorporated were variations in physical measurements as observed in the above-mentioned IAEA-RCA CRP (5, 8-10). The weight of the skeleton was adjusted following the revised values in Publication 70 in the previous report (11) but that changes were not considered in this work. This paper will report basic shared and non-shared characteristics of “Reference Man” for Asians and ICRP Reference Man.

MATERIALS AND METHODS

Physical data were obtained from the periodical national statistics in Japan (12-13) and similar data on students and adults in China have become available recently (14-16). Data from the populations in India were also reported (17,18). Secular trends were discussed in these populations (16, 19). Lengths of limbs, body surfaces, skin fold thickness were obtained (12, 20). Body lipid was principally estimated by Nagamine’s method and the body ^{40}K content. Masses of internal organs were obtained at Tokyo Medical Examiner’s Office and 5370 sets of data out of 18,000 cases were selected for utmost normalcy (8, 22). Reported data by forensic studies may include any loss of blood (23, 24). Mass of different bones from 17 skeletons was available (9, 10). Single and multiple regressions of the organ mass to the body height and weight were only positive for the ages below 20 (9, 10). Body composition data was studied using the LBM concept (10, 21). Total blood content is important when to consider the mass of parenchyma from the weight of organ in situ.

Ratios in masses between the Asian adult female and male were obtained for all organs, tissues and their content as well as blood content. These ratios were applied to the mass of organs, tissues and blood content of ICRP Reference Man male to estimate those of possible female counterpart.

RESULTS AND DISCUSSION

The feature of the Asian Reference adult male and female are shown in Table 1 in comparison with those of ICRP Reference Man and its revised version (1, 2, 10). The individual mass of organs, tissues, their contents and volume of the total blood are shown in Table 2. From calculated ratios between ICRP Reference Man and Asian man model (as shown as CRM/ARMM), it may be found that these data for Asians are different from those of Europeans but the differences are generally not large. It may be seen that masses of central nervous system and reproductive organs, i.e. testes in the two populations are essentially the same (CRM/ARMM =1.00). Differences are seen, for instance, in the body weight and lipid content,1.22 and 1.35, respectively. A significant difference in the liver weight should be noted , i.e. 1.13. These may well be explained by the common understanding that humans are of a single species and have adapted to different habitat and habit.

Within the Asian models, female-to-male ratios were calculated being based on observed values and,

in case that such data is not directly available, relevant estimates, as shown in the ARMF/ARMM column. The ratios are generally smaller than unity, e.g. 0.85 for the body weight and, 0.90, 0.88, 0.76 and 0.89 for the brain, liver, skeleton and thyroid, respectively. Some other organs have the same or larger ratios, e.g. the adipose tissue (1.18), body fat (1.30), cerebellum (1.00), parathyroid (1.17), pituitary gland (1.07) and breast (13.6). This adult female model for Asians was previously developed being based on the normal data on the physique and organ mass although its number of organ data was smaller than in the normal male (5, 11). In this work, it was assumed that the found and estimated female-to-male ratios can be applied to the European populations and the masses and blood content in the female were derived from those of ICRP Reference Man adult male (1) using the above ratios (ARMF/ARMM). The results are shown in Table 2, column CRF. This attempt was made partly because recent female data for Europeans are not directly available to the authors.

As above, male and female models for Asians and Europeans have become available although these, especially the female model of the latter, are still in the stage of speculation while the assumptions adopted here may not be too unreasonable. The Asians and European models might share similar characteristics for many components of the body while some data slightly differ each other.

CONCLUSION

Reference man models for the male and female adult for the Asians as well as for the females for the European population were described, the latter being developed from the ICRP Reference Man utilizing the female-to-male ratios in the Asian Reference Man. It is hoped that the present data will be useful in further considering Reference man models being firmly based on the normal data on various characteristics of humans.

Table 1 Reference man model for Asian male and female adult as compared with revised ICRP Reference Man

Parameter	Asians (1998)		ICRP Reference Man (1975)	Revised ICRP Reference Man (1995)	
Age (y)	35 (20-50)		20-30	35 (20-50)	
Sex	Male	Female	Male	Male	Female
Body Weight (kg)	60	51	70	73	60
Height (cm)	170	160	170	176	163
Race	Mongoloid and South Caucasoid		Caucasoid	Caucasoid	
BMI	22	22	24	24	23

Table 2 Mass of organs and tissues, and volume of total blood for Asian Reference Man Male adult (ARMM) and Female adult (ARMF) as compared with those for ICRP Reference Man adult (CRM) and Female adult (CRF).

Organ, tissue or component	Weight in situ (g)							Total blood (ml)				
	ARMM	ARMF	ARMF/ARMM	CRM	CRF	CRM/ARMM	CRF/ARMF	ARMM	ARMF	ARMF/ARMM	CRM	CRF
*1 Total body	60000	51000	0.85	73000	60000	1.22	1.18	4500	3600	1.25	5200	4160
1a Total soft tissue	52000	45000	0.87	60000	51923	1.15	1.15				. .	. .
2 Adipose tissue	11000	13000	1.18	15000	17727	1.36	1.36	150	120	1.25	270	216
3 Subcutaneous (hypodermis)*	5500 *	7000	1.27	7500 *	9545	1.36	1.36	75 *	65	1.15	140 *	121
4 Other separable*	3500 *	4500	1.29	5000 *	6429	1.43	1.43	55 *	45	1.22	90 *	74
5 Interstitial	700	530	0.76	1000	757	1.43	1.43				. .	. .
6 Yellow marrow (skeleton)	1300	990	0.76	1500	1142	1.15	1.15	20	10	2.00	20	10
7 Adrenals (2)	14 *	13	0.93	14 *	13	1.00	1.00	1.1 *	1	1.10	3.3 *	3
8 Aorta*	90 *	68	0.76	100 *	76	1.11	1.11	*			. . *	. .
9 Contents*	170 *	130	0.76	190 *	145	1.12	1.12	150 *	120	1.25	180 *	144
*10 Blood	4800	3800	0.79	5500	4354	1.15	1.15	4500	3600	1.25	5200	4160
11 Plasma	2700	2100	0.78	3100	2411	1.15	1.15				. .	. .
12 Erythrocytes	2100	1700	0.81	2400	1943	1.14	1.14				. .	. .
13 Blood vessels*	180 *	140	0.78	200 *	156	1.11	1.11	*			. . *	. .
14 Contents (except aorta and pulmonary)*	2100 *	1600	0.76	3000 *	2286	1.43	1.43	2000 *	1500	1.33	2900 *	2175
*15 Body fat	10000	13000	1.30	13500	17000	1.35	1.31				. .	. .
16 Essential	1200	1000	0.83	1500	1250	1.25	1.25				. .	. .
17 Nonessential	8800	12000	1.36	12000	16364	1.36	1.36				. .	. .
*18 Body water	37000	29000	0.78	42000	32919	1.14	1.14				. .	. .
19 Extracellular	16000	12500	0.78	18000	14063	1.13	1.13				. .	. .
20 Intracellular	21000	16500	0.79	24000	18857	1.14	1.14				. .	. .
21 Cartilage (skeleton)	900	700	0.78	1100	856	1.22	1.22				. .	. .
27 Central nervous system	1500 *	1400	0.93	1430 *	1335	0.95	0.95	25 *	23	1.09	32 *	29
23 Tendons and fascia	1200	910	0.76	1400	1062	1.17	1.17				. .	. .
24 Periarticular tissue	1300	990	0.76	1500	1142	1.15	1.15				. .	. .
25 Other connective tissue	400	300	0.75	500	375	1.25	1.25				. .	. .
26 Separable connective tissue*	1400 *	1100	0.79	1600 *	1257	1.14	1.14	*			. . *	. .

*27	Central nervous system*	1500	*	1400	0.93	1430	*	1335	0.95	0.95	25	*	23	1.09	32	*	29
*28	Brain	1470		1320	0.90	1400		1257	0.95	0.95					31		. .
29	Cerebrum	1280		1130	0.88	1200		1059	0.94	0.94					. .		. .
30	Cerebellum	160		160	1.00	150		150	0.94	0.94					. .		. .
31	Brain stem	30		30	1.00	30		30	1.00	1.00					. .		. .
32	Spinal cord	30		30	1.00	30		30	1.00	1.00					. .		. .
33	Contents (cerebrospinal fluid)*	110	*	83	0.75	120	*	91	1.09	1.09		*			. .	*	. .
*34	Eyes (2)*	15	*	12	0.80	15	*	12	1.00	1.00		*			. .	*	. .
*35	Lenses (2)	0.4		0.3	0.75	0.4		0.3	1.00	1.00					. .		. .
36	Gall bladder*	8	*	6	0.75	10	*	8	1.25	1.25		*			. .	*	. .
37	Contents (bile)*	50	*	38	0.76	62	*	47	1.24	1.24		*			. .	*	. .
38	GI tract*	1100	*	850	0.77	1200	*	927	1.09	1.09		*			. .	*	. .
39	Contents (food plus digestive fluids)*	950	*	730	0.77	1005	*	772	1.06	1.06		*			. .	*	. .
40	Esophagus	40		30	0.75	40		30	1.00	1.00					. .		. .
41	Stomach	140		110	0.79	150		118	1.07	1.07	4.4		3.5	1.26	6		5
42	Contents	240		180	0.75	250		188	1.04	1.04					. .		. .
43	Intestine	920		710	0.77	1000		772	1.09	1.09					. .		. .
44	Contents	710		550	0.77	750		581	1.06	1.06					. .		. .
45	Small intestine	590		450	0.76	640		488	1.08	1.08					. .		. .
46	Contents	350		270	0.77	400		309	1.14	1.14					. .		. .
47	Duodenum	50		40	0.80	60		48	1.20	1.20					. .		. .
48	Jejunum	260		200	0.77	280		215	1.08	1.08					. .		. .
49	Ileum	280		210	0.75	300		225	1.07	1.07					. .		. .
50	Large intestine	330		260	0.79	370		292	1.12	1.12					. .		. .
51	Contents	360		280	0.78	355		276	0.99	0.99					. .		. .
52	Upper large intestine	180		140	0.78	210		163	1.17	1.17					. .		. .
53	Contents	220		170	0.77	220		170	1.00	1.00					. .		. .
54	Ascending colon and cecum	80		60	0.75	90		68	1.13	1.13					. .		. .
55	Transverse colon	100		80	0.80	120		96	1.20	1.20					. .		. .
56	Lower large intestine	150		120	0.80	160		128	1.07	1.07					. .		. .
57	Contents	140		110	0.79	135		106	0.96	0.96					. .		. .
58	Descending colon	80		60	0.75	90		68	1.13	1.13					. .		. .
59	Sigmoid colon	50		40	0.80	50		40	1.00	1.00					. .		. .
60	Rectum	20		20	1.00	20		20	1.00	1.00					. .		. .
61	Hair*	25	*	75	3.00	20	*	60	0.80	0.80		*			. .	*	. .

*62	Heart*	380	*	320	0.84	330	*	278	0.87	0.87	89	*	76	1.17	53	*	45
63	Contents (av.)*	400	*	300	0.75	500	*	375	1.25	1.25	380	*	290	1.31	500	*	382
*64	Kidneys (2)*	320	*	280	0.88	310	*	271	0.97	0.97	49	*	42	1.17	70	*	60
65	Larynx*	27	*	20	0.74	28	*	21	1.04	1.04		*			. .	*	. .
*66	Liver*	1600	*	1400	0.88	1800	*	1575	1.13	1.13	180	*	150	1.20	250	*	208
*67	Lung*	1200	*	910	0.76	1000	*	758	0.83	0.83	710	*	540	1.31	530	*	403
68	Parenchyma (includes bronchial tree plus capillary blood)	500		380	0.76	570		433	1.14	1.14	90		68	1.32	. .		. .
*69	Blood (arterial and venous)	700		530	0.76	430		326	0.61	0.61	660		500	1.32	400		303
70	Bronchial tree	26		20	0.77	30		23	1.15	1.15					. .		. .
71	Lymphocytes	1300		990	0.76	1500		1142	1.15	1.15					. .		. .
72	Lymphatic tissue	600		450	0.75	700		525	1.17	1.17					. .		. .
73	Lymph nodes (dissectible)*	220	*	170	0.77	250	*	193	1.14	1.14	3	*	2.2	1.36		*	
74	Miscellaneous*	2500	*	790	0.32	2953	*	933	1.18	1.18		*			. .	*	. .
75	Solid soft tissue	2100		540	0.26	2600		669	1.24	1.24					. .		. .
76	Fluid (synovial, pleural, etc.)	400		250	0.63	350		219	0.88	0.88					. .		. .
*77	Muscle (skeletal)*	25000	*	20000	0.80	30000	*	21796	1.20	1.09	410	*	360	1.14	700	*	615
78	Nails (20)*	3	*	2.3	0.77	3	*	2	1.00	1.00		*			. .	*	. .
79	Pancreas*	130	*	110	0.85	100	*	85	0.77	0.77	16	*	13	1.23	. .	*	. .
80	Parathyroid (4)*	0.12	*	0.14	1.17	0.12	*	0.14	1.00	1.00		*			. .	*	. .
81	Pineal*	0.18	*	0.14	0.78	0.18	*	0.14	1.00	1.00		*			. .	*	. .
*82	Pituitary*	0.6	*	0.64	1.07	0.6	*	0.6	1.00	1.00	0.06	*	0.07	0.86	0.056	*	0.065
83	Prostate*	12	*		0.00	13	*		1.08			*			. .	*	. .
83a	Contents*	4	*		0.00	3	*		0.75			*				*	
84	Salivary glands (6)*	82	*	62	0.76	85	*	64	1.04	1.04	6.1	*	5	1.22	8.2	*	6.7
85	Parotid (2)	48		36	0.75	50		38	1.04	1.04	4.1		3.5	1.17	4.8		4.1
86	Submaxillary (2)	24		18	0.75	25		19	1.04	1.04	2.1		1.8	1.17	2.4		2.1
87	Sublingual (2)	10		7.6	0.76	10		8	1.00	1.00	0.65		0.6	1.08	1.0		0.9
*88	Skeleton*	8400	*	6400	0.76	11000	*	7619	1.31	1.19	210	*	180	1.17	350	*	300
*89	Bone	4500		3400	0.76	5000		3778	1.11	1.11	160		140	1.14	250		219
90	Cortical	3600		2700	0.75	4000		3000	1.11	1.11					. .		. .
91	Trabecular	900		700	0.78	1000		778	1.11	1.11					. .		. .
92	Red marrow	1000		780	0.78	1500		1170	1.50	1.50	45		34	1.32	80		60
93	Yellow marrow	1300		990	0.76	1500		1142	1.15	1.15	15		11	1.36	20		15
94	Cartilage	900		700	0.78	1100		856	1.22	1.22					. .		. .

95	Periarticular tissue (skeletal)	700	530	0.76	900	681	1.29	1.29				. .	. .
96	Skin*	2400 *	1800	0.75	2600 *	1950	1.08	1.08	47 *	40	1.18	65 *	55
97	Epidermis	100	76	0.76	100	76	1.00	1.00				. .	. .
98	Dermis	2300	1700	0.74	2500	1848	1.09	1.09				. .	. .
*99	Hypodermis (see adipose tissue)	5500	7000	1.27	7500	9545	1.36	1.36				. .	. .
100	Spleen*	140 *	120	0.86	180 *	154	1.29	1.29	65 *	60	1.08	90 *	83
101	Teeth (32)*	45 *	34	0.76	46 *	35	1.02	1.02	*			. . *	. .
102	Enamel	10	7.3	0.73	10	7	1.00	1.00				. .	. .
103	Dentin	34	26	0.76	35	27	1.03	1.03				. .	. .
104	Pulp	1	0.7	0.70	1	1	1.00	1.00				. .	. .
105	Testes (2)*	37 *		0.00	35 *		0.95		2.8 *			1.3 *	
*106	Thymus*	30 *	29	0.97	20	19	0.67	0.67	6.6 *	6.3	1.05	6.0	5.7
*107	Thyroid*	19 *	17	0.89	20 *	18	1.05	1.05	2.6 *	2.3	1.13	3.6 *	3.2
108	Tongue*	67 *	51	0.76	70 *	53	1.04	1.04	*			. . *	. .
109	Tonsils (2 palatine)*	4 *	3	0.75	4 *	3	1.00	1.00	*			. . *	. .
110	Trachea*	9 *	6.8	0.76	10 *	8	1.11	1.11	*			. . *	. .
111	Ureters (2)*	14 *	15	1.07	16 *	17	1.14	1.14	*			. . *	. .
112	Urethra*	9 *	6	0.67	10 *	7	1.11	1.11	*			. . *	. .
113	Urinary bladder*	40 *	30	0.75	45 *	34	1.13	1.13	*			. . *	. .
114	Contents (urine)*	100 *	85	0.85	102 *	87	1.02	1.02	*			. . *	. .
115	Breast*	22 *	300	13.64	26	360	1.18	1.20	*				
116	Ovary*		11			11		1.00					8
117	Penis*	47 *			47		1.00		15 *			28	
118	Uterus*	*	70			80		1.14	*	30			34
119	Uterine tube*	*	10			10		1.00	*	5			5
120	Vagina*	*	25			25		1.00	*	10			
Total body		60000	51000	0.85	73000	60000	1.22	1.18	4500	3600	1.25	5200	4160
Total of asterisked quantities		60000	51000	0.85	73000	60000	1.22	1.18	4500	3600	1.25	5972	4778

(Asterisked quantities make up the totality of Reference Man)

ACKNOWLEDGEMENTS

The authors would like to express their thanks to the colleagues in Japan and overseas for their co-operation and support. They especially thank Dr. O. Matsuoka, Dr. H. Matsudaira, Dr. S. Kobayashi and Dr. T. Terasima as well as late Dr. S. Takahashi. They also thank Dr. R. V. Griffith, Dr. M. Cristy and Dr. K. F. Eckerman as well as Dr. C. R. Richmond and Dr. Chen X.-A.

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February 4, 2000

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Dear Sir:

I would like to send my paper, No. 00602, Poster No. 195 as a MS Word file in a 3.5-in. FD as attached. It includes corrections found in the previously manuscript that was sent by fax on February 1.

Thank you.

Truly yours,

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