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Empirical formulae for the proportionate growth of the human fetus.

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The following is a summary of a quantitative study of the growth of 70 external dimensions of the human body in the fetal period. Of these dimensions, 22 were of the head and neck, 28 of the trunk and pelvis, 16 were of the extremities, and 4 involved more than one major division of the body. Each dimension was determined from a series of preserved specimens, the number of cases ranging from 207 to 369.

Each dimension was plotted against the crown-heel or total body-length. In 19 instances the resulting curves approximated straight lines; in 41 instances the curves approximated straight lines, except at their upper ends. In 9 instances the relation could be approximated by two straight lines meeting in about the middle of the distribution. In one instance the relation in the lower ranges was expressed by a straight line, and in the upper by a curved one.

It was found that the departure from a straight line of the 41 curves mentioned above was due to the effects of birth moulding, to changes in the form of the chest following birth, and to formalin artifacts. Experimental studies were made of each of these factors. Corrections for head moulding were determined by the measurements of heads of children delivered by Cesarean section, and second twins born with breech presentation. The chest changes were determined by measurements of living newborn infants. The changes produced by formalin artifacts were also worked out quantitatively. The application of the corrections thus obtained to the upper values for the dimensions of this group reduced these curves to straight lines. The remaining 9 dimensions were mainly measurements in the anterior median line of the body. Their departure from straight lines is probably due to posture effects, but we have been unable to work out correction coefficients for them. Three remaining curves show

EMPIRICAL FORMULAE FOR EXTERNAL BODILY DIMENSIONS IN THE FETAL PERIOD

Dimension	Number of cases	Constants of Empirical Formulae as determined by:						Average Weighted Residuals by:					
		Graphic method		Method of averages		Method of least squares		Graphic method		Method of averages		Method of least squares	
		a	b	a	b	a	b	mm.	Per cent.	mm.	Per cent.	mm.	Per cent.
Crown-rump length (sitting-height)	356	0.66	+ 5.0	0.669	+ 4.81	0.671	+ 4.14	2.75	1.4	2.80	1.75	2.85	1.93
Spine length	296	0.43	+ 4.0	0.426	+ 4.22	0.429	+ 3.47	2.77	1.97	2.92	1.97	2.80	1.97
Crown to umbilicus	234	0.52	+ 5.5	0.51	+ 6.74	0.52	+ 6.06	1.77	1.33	1.59	0.92	1.68	1.10
Crown to sternal notch †	284	0.3	+ 4.0	0.297	+ 5.05	0.289	+ 6.34	3.30	3.26	2.08	2.22	2.37	2.66
		0.24	+22.0	0.210	+24.31	0.214	+22.69						
Occipito-frontal circumference	367	0.675	+13.0	0.674	+13.33	0.675	+13.21	4.08	1.86	4.06	1.87	4.07	1.89
" " diameter	369	0.235	+ 4.0	0.221	+ 6.41	0.210	+ 9.38	1.91	1.95	1.55	2.59	1.98	4.06
Bi-parietal diameter	369	0.19	+ 2.0	0.182	+ 3.57	0.184	+ 3.08	1.92	2.83	1.32	2.27	1.47	2.42
Vertical head height	332	0.227	+ 5.0	0.219	+ 6.49	0.217	+ 7.17	0.98	1.42	1.29	2.37	1.45	2.76
Bi-acromial diameter	278	0.225	± 0.0	0.232	− 1.52	0.236	− 2.50	1.74	2.26	2.03	3.46	2.28	4.24
Circumference at nipples	273	0.6	± 0.0	0.594	+ 1.82	0.595	+ 1.37	3.70	1.78	3.82	1.85	3.71	1.74
Transverse diameter at nipples	274	0.2025	± 0.0	0.206	− 0.39	0.203	+ 0.29	1.06	1.81	0.92	1.52	1.06	2.08
Antero posterior " " "	271	0.175	± 0.0	0.171	+ 0.19	0.172	± 0.0	1.25	3.27	1.59	3.87	1.55	3.68
Circumference at umbilicus	208	0.553	− 5.5	0.547	− 5.52	0.542	− 4.02	9.09	3.75	9.56	3.75	10.10	3.94
Transverse diameter at umbilicus	207	0.19	− 2.0	0.195	− 3.00	0.195	− 3.05	2.01	2.53	1.94	2.44	1.93	2.46

Antero-posterior diameter at umbilicus	208	0.165	− 1.0	0.164	− 1.03	0.167	− 1.89	3.68	5.22	3.77	5.19	3.75	5.15
Sternal notch to xiphi-sternal junction	233	0.11	− 1.5	0.113	− 2.19	0.111	− 1.84	0.71	3.79	0.65	3.76	0.66	3.70
Xiphi-sternal junction to pubis *	226	0.19	+ 1.5	0.172	+ 3.62	0.179	+ 2.58	2.20	2.74	1.35	1.96	1.37	2.08
		0.26	− 16.0	0.281	−23.15	0.276	−21.23						
Pelvis height	245	0.155	− 4.0	0.153	− 3.83	0.154	− 4.15	0.67	2.46	0.56	2.00	0.53	2.07
Interspinous diameter	245	0.145	− 2.5	0.147	− 2.96	0.148	− 3.20	0.77	1.48	0.78	1.68	0.81	2.01
Intercristal diameter	246	0.1625	− 2.5	0.166	− 3.83	0.166	− 3.65	1.10	2.54	0.86	2.08	0.88	2.06
Intertrochanteric diameter	244	0.1775	− 3.5	0.186	− 5.64	0.187	− 5.91	1.50	2.68	1.39	3.30	1.45	3.62
Upper extremity length	314	0.40	− 4.0	0.40	− 3.40	0.40	− 3.35	1.12	1.20	1.15	1.45	1.16	1.11
Arm length	307	0.155	− 0.5	0.152	+ 0.27	0.152	+ 0.40	0.69	1.69	0.64	2.08	0.64	2 18
Forearm length	305	0.13	− 1.5	0.13	− 0.50	0.13	− 0.58	0.64	1.94	0.50	2.12	0.49	2.04
Hand length	304	0.12	− 3.0	0.12	−13.74	0.12	− 3.35	0.51	2.44	0.43	2.35	0.57	1 94
Middle finger length	292	0.075	− 3.0	0.07	− 2.76	0.07	− 2.61	0.34	3.69	0.36	3.58	0.42	3 58
Arm circumference	294	0.195	− 8.0	0.193	− 7.11	0.194	− 7.49	1.87	3.26	1.88	2.96	1.87	2 84
Lower extremity length	315	0.43	− 7.0	0.429	− 7.22	0.432	− 8.29	1.28	1.62	1.33	1.49	1 04	1 13
Thigh length	301	0.19	− 2.0	0.19	− 1.68	0.19	− 1.65	0.63	1.30	0.60	1 39	0.61	1 41
Leg length	299	0.2	− 4.5	0.20	− 3.34	0.20	− 3.51	0.92	1.77	0.58	1.03	0.55	1 01
Foot height	298	0.04	− 1.5	0.04	− 2.44	0.045	− 2.68	0.54	5.72	0.41	5.66	0.48	6 93
Foot length	299	0.16	− 6.5	0.16	− 6.11	0.156	− 5.53	0.56	3.88	0.61	3 15	0.61	3 19
Thigh circumference	294	0.31	−13.0	0.31	−13.76	0.314	−14.26	2.91	3.12	3.05	3.65	3 11	3.98

† *Upper constants for use between 5 and 30 cm. crown-heel length; lower constants for use between 30 and 55 cm. crown-heel length*
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deviations which are probably due to faulty technique and to the combination of several experimental errors.

Since all of the dimensions which we have been able to analyze in detail approximate straight lines, when plotted against total body length, they may be expressed by formulæ of the general type:

$$D = aL \pm b$$

where "D" is the dimension in question, "L" is the total body-length, "a" is a constant in the form of a decimal fraction and "b" is a second constant. These constants have been determined by graphic methods and by the methods of averages and of least squares, on the basis of the means for dimension length and total body-length for the 5 cm. intervals of total body-length between 5 and 55 cm. inclusive. The preceding table gives constants for the formulæ for 33 of the more important dimensions of the series as determined by these methods. The columns forming the left division of the table give the average weighted absolute and percentage deviations (summed without regard to sign) of the observed from the calculated 5 cm. range averages. The constants as given are for use with dimensions taken in millimeters.[1]

Since all of the dimensions of the body which we were able to analyze in detail are of the straight line type, it follows that the growth in length, girth and diameter of the various external divisions of the body is directly proportional to the growth in total body-length in the fetal period (from at least 3 fetal months to birth). In other words, while each dimension has its own rate of growth with respect to body-length, this rate does not change in the period under consideration.

When the formulæ are grouped according to regions, it is found that practically all head and neck measurements have a positive second or "b" constant. The "b" constants for the formulæ for the chest dimensions may be zero, or small positive or negative ones. The "b" constants for the formulæ for the abdomen and pelvis and extremities are, with one exception (arm length by least squares), negative. Since the "b" constant is an indicator of the amount of growth prior to the period under con-

[1] A large number of empirical formulæ for the obstetrical dimensions of the head have been published elsewhere. (Calkins, *Am. J. Obstet. and Gyn.*, 1922, iv, 109.)

sideration, it is evident that the head and neck have grown more proportionately than the body as a whole in the embryonic period, while the thorax has undergone about the same relative amount of growth as the body as a whole. The lower part of the abdomen, the pelvis and the extremities have grown relatively less. This forms a quantitative demonstration of the application of the law of developmental direction to the growth of the human body in prenatal life.

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The antigenic properties of pneumococci and streptococci treated with sodium ricinoleate.

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The property of sodium ricinoleate to neutralize bacterial toxins and destroy the pathogenicity of some of the pathogenic bacteria has been emphasized in a series of papers published from this laboratory.[1, 2, 3] The present paper concerns the effect of sodium ricinoleate upon the pathogenic and antigenic properties of the pneumococcus and streptococcus scarlatinæ.

If a solution of sodium ricinoleate is added to a virulent culture of the pneumococcus, so that the final dilution of soap is 0.1 per cent, the micro-organism loses its pathogenicity instantly. Ten cc. or more of such a culture may be injected into rabbits intraperitoneally without ill effects. Twenty-four hours after such an injection, large amounts of agglutinins are present in the blood stream. Following such treatment, the animals resist many lethal doses of pneumococci. The serum of rabbits thus immunized protects normal rabbits against intraperitoneal and intravenous infections.

We have studied the effect of sodium ricinoleate upon one strain of streptococcus scarlatinæ. It loses its power to grow upon culture media in less than five minutes when treated with

[1] PROC. SOC. EXP. BIOL. AND MED., 1923, xx, 229.
[2] Ibid., 1924, xxi, 278.
[3] Ibid., 1924, xxii, 194.