ESTIMATION OF TOTAL BODY SODIUM BY ISOTOPIC DILUTION.

II. STUDIES ON INFANTS AND CHILDREN: AN EXAMPLE OF A CONSTANT DIFFERENTIAL GROWTH RATIO^{1, 2}

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In contrast to the lack of such information on adults, the literature does contain reports of the direct chemical analysis of a number of fetuses and newborn infants for sodium. Data are available, therefore, with which to compare directly results obtained by the isotopic dilution method. Our study of total body sodium in man, for which data on adults are presented elsewhere (2), was consequently broadened to include infants and children. Since it has been known for some time that the sodium content of the infant, on a per kilogram basis, is higher than that of the adult (3), we set out to investigate the possibility that there was some regularity to the process of chemical growth. That a chemical growth pattern, capable of being expressed in simple mathematical terms, does indeed exist, at least with regard to sodium accumulation, will be demonstrated by the data to follow.

Aside from carcass analysis, the isotopic dilution method is the only direct approach available for estimation of total body sodium and for the study of chemical growth. Cumulative balances fail to provide a satisfactory answer, presumably through inability to account accurately for cutaneous mineral losses. For example, balance studies on normal infants and children have yielded values for sodium retention varying from 93 to 915 meq. per Kg. of body weight gain (4, 5).⁴

This paper reports our studies of the estimation of total body sodium by the isotopic dilution method in 21 infants and children. The various

assumptions which had to be made in applying this method to the estimation of total body sodium in man have already been discussed (2).

METHODS

The methods used are essentially those employed in the studies of adults (2). Radiosodium²⁴, manufactured in the Washington University cyclotron, and prepared in our laboratory as sterile isotonic saline, was given intravenously in doses of 1 to 1½ microcuries per Kg. of body weight.⁵

Procedures used in assaying the serum and urine samples for radiosodium and inactive sodium have already been presented (2).

The subjects employed were infants and children residing in the wards of the Saint Louis Children's Hospital, whose general nutritional and physical status was judged to be normal and who were free from cardiac, renal, or allergic disease. No patients who were convalescing from surgical operations or who were receiving parenteral fluid therapy were included; none had loose stools. They consumed the normal hospital diet (evaporated milk-Karo formulas in the case of infants) during the experiments. Reasons for hospitalization are listed in Table I to follow.

Calculations were made as follows: serum obtained 18–24 hours (17 hours in three infants) following the intravenous administration of a known amount of radiosodium was analyzed for sodium and radioactive sodium, and urine was collected over the same interval of time. Assuming complete equilibration:

$$\text{total exchangeable sodium (TES)} = \frac{\text{Na}^{24} \text{ injected} - \text{Na}^{24} \text{ excreted}}{\text{serum Na}^{24} / \text{serum sodium}}$$

This period of equilibration was chosen for reasons presented elsewhere (2). The amount of sodium administered with the radiosodium is negligible. No attempt was made to take into account the Donnan phenomenon, slight

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² A preliminary report of these studies has been published elsewhere (1).

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⁴ Calculated from the author's data.

⁵ The total radiation dose received by the experimental subject from this amount of Na²⁴ is of the order of 0.11 to 0.17 roentgen equivalent physical (6). This calculation was made for subjects of adult size; since gamma radiation accounts for approximately 75% of the total dose, it is possible that recalculation of the amount of radiation received by the young infant would yield a lower value.

differences in diffusibility between Na^{24} and Na^{23} ions, or the possibility that small amounts of radiosodium might be excreted by way of the skin or gastrointestinal tract.

RESULTS

The results obtained during a study of 21 healthy infants and children are presented in Table I, in which the subjects are listed in order, according to weight. Total exchangeable sodium has been calculated on the basis of weight, height, and surface area. None of these result in constant unit values for TES, for the values change throughout the growing period in each instance. The difference between infants and older children is most marked on the basis of height, the values indicating a four-fold increase of total body sodium per centimeter of height, whereas sodium content per square meter of surface area increased by only 25% (approximately) over the span of growth represented by our subjects. The trend in the data is opposite in direction when calculations are made on the basis of weight. In the very young infant, values are highest, averaging 76 meq. sodium per Kg. of body weight, and there is a progressive decline with increasing weight

until adult values (41.9 meq. per Kg. for males, 39.5 meq. per Kg. for females [2]) are attained. Since sodium content is constantly changing with growth regardless of whether weight, height, or surface area is employed as a reference, body mass was selected as the logical parameter of body size with which to attempt to correlate sodium content. It will be shown, in the discussion to follow, that there is a recognizable mathematical relation, not necessarily dependent on age, between the amount of sodium in the body, and body mass, as measured by weight.

DISCUSSION

In the study of adult subjects (2) it was realized that mixing of injected Na^{24} with body sodium may not be quite complete at the end of 18–24 hours, although curves of the apparent volume of Na^{24} distribution and of serum specific activity revealed a leveling off at that time. Moreover, it was concluded that prolongation of the equilibration period would be of little benefit and, in fact, might intensify errors due to extrarenal losses of Na^{24} . Studies of bone specific activity revealed that complete Na^{24} mixing in bone

TABLE I
Total exchangeable sodium in infants and children

Subject	Age	Sex	Weight	Height	Surface area	Equilibration time	TES	Meq. per Kg.	Meq. per cm.	Meq. per m^2	Reason for hospitalization
			Gm.	cm.	m^2	hours	meq.				
G. S.	2 wks.	M	1795	46	0.149	19	148	82.5	3.22	994	Premature
R. C.	6 wks.	M	2155	47	0.162	20	187	86.8	3.98	1155	Premature
R. G.	2½ wks.	M	2375	48	0.172	20	187	78.7	3.90	1088	Premature
A. J.	3 wks.	M	2590	45	0.170	17½	184	71.2	4.09	1082	Premature
G. E.	4 wks.	M	3530	53	0.218	21	259	73.4	4.89	1188	Methemoglobinemia; recovered
L. L.	2 mo.	F	3665	55	0.230	17	242	66.0	4.40	1053	Ruminator
E. H.	2½ mo.	M	4870	59	0.272	17	336	69.0	5.70	1237	Roseola infantum; recovered
G. J.	14 mo.	M	6960	68	0.348	23½	364	52.3	5.20	1018	Premature infant ? lye burns of esophagus
R. C.	4½ mo.	M	7200	67	0.350	17½	406	56.4	6.05	1160	? skull fracture
L. O.	12 mo.	M	11,480	84	0.503	18	564	49.1	6.60	1100	Mental defective
S. M.	22 mo.	M	11,630	81	0.490	23	504	43.4	6.21	1030	? hydrocephalus
J. D.	13 mo.	M	12,750	82	0.515	18½	691	54.4	8.44	1340	Osteomyelitis spine
R. H.	3½ yrs.	M	14,700	99	0.620	18	847	57.6	8.56	1365	Tbc suspect
E. R.	3 yrs.	M	15,400	103	0.660	19½	863	56.1	8.37	1308	Hernia, pre-op.
B. T.	3½ yrs.	M	18,400	101	0.700	17	938	51.0	9.30	1340	Hematoma forehead
J. H.	6 yrs.	M	21,100	123	0.860	18	1107	52.4	9.00	1290	Tbc suspect
C. M.	10 yrs.	F	23,800	137	0.970	19½	1163	48.9	8.50	1200	? chorea
J. K.	11 yrs.	M	31,100	139	1.10	18	1790	57.6	8.44	1630	Idiopathic epilepsy
G. B.	14 yrs.	M	37,600	146	1.25	23	1478	39.3	10.2	1190	? coarctation aorta
J. P.	13 yrs.	M	39,000	158	1.33	18	1992	51.0	12.6	1500	Behaviorism
M. K.	11 yrs.	F	52,800	165	1.56	23	1862	35.2	11.3	1193	Epilepsy, idiopathic
L. M.	14 yrs.	M	56,800	165	1.61	20	2440	43.0	14.8	1515	Small osteosarcoma, tibia

TABLE II

Comparison of total body sodium measured by direct chemical analysis and by isotopic dilution in young infants, meq. per Kg.*

Chemical analysis*					Isotopic dilution				
Number of subjects	Weight range, Gm.	Meq. per Kg.			Number of subjects	Weight range, Gm.	Meq. per Kg.		
		Max.	Min.	Average			Max.	Min.	Average
11	2476-3360	93.0	58.5	75.9	6	1795-3665	86.8	66.0	76.4

* Calculated from the literature (7-11).

would probably necessitate prolonging the equilibration period considerably; unfortunately only one of the samples analyzed for specific activity was from a child. About 40% of the bone sodium would appear to be exchanged at the end of 18-24 hours in the adult; however, the difficulties encountered in determining the specific activity of bone sodium make us hesitate to place too much reliance on this value without further study.

TABLE III
Total body sodium in the human fetus

Reference	Weight	Fetal age, lunar months	Total Na	Na per Kg.
	Gm.		meq.	meq.
(7)	18.2	3.0	0.9	50.0
(7)	23.9	3.2	0.8	34.5
(7)	59.4	3.7	4.5	76.4
(7)	114.5	4.3	11.6	101.1
(7)	259.0	5.1	29.9	103.7
(7)	335.0	5.4	31.3	94.4
(7)	490.0	5.7	50.5	103.3
(8)	522.0	4.5-5.0	55.4	106.0
(8)	570.0	5.0-5.5	67.5	118.5
(7)	570.0	6.4	53.5	94.4
(7)	590.0	6.2	55.9	95.3
(8)	800.0	5.5-6.0	74.4	93.0
(7)	960.0	7.6	98.4	102.5
(12)	970.0	6.7	105.0	108.5
(7)	1010.0	7.2	83.7	83.0
(8)	1165.0	6.7	105.5	90.5
(7)	1205.0	7.7	104.8	87.6
(8)	1285.0	7.2	116.1	90.5
(12)	1420.0	6.7-7.8	134.0	94.5
(7)	1545.0	8.2	136.0	88.5
(7)	1555.0	8.2	127.2	82.0
(7)	1615.0	8.4	143.3	89.2
(11)	2476.0	Term	200.0	80.9
(11)	2616.0	Term	176.0	67.4
(9)	2680.0	Term	225.0	84.0
(11)	2683.0	Term	179.5	66.9
(8)	2720.0	Term	253.0	93.0
(11)	2755.0	Term	196.0	71.3
(7)	2915.0	Term	240.4	76.2
(11)	3080.0	Term	284.0	92.4
(10)	3211.0	Term	217.5	67.7
(8)	3300.0	Term	193.0	58.5
(11)	3360.0	Term	259.0	77.1

The literature contains reports of sodium analysis of the complete carcass (in many the meconium was removed) of 11 term fetuses. Comparison with these data provides the only way in which our own measurements can be directly evaluated. Values obtained by the two methods are presented in condensed form in Table II, in which the analyses for term fetuses from the literature are set against our analyses (by isotopic dilution) for young infants. Agreement between these two groups of roughly comparable weight is surprisingly good, and suggests that total sodium can be measured, at least in the young infant, by the isotopic dilution method. Most of the sodium of the infant, according to this comparison, would be exchangeable with radiosodium. This is in contrast to the adult, in whom as much as 18% of the body sodium may escape detection by the isotopic dilution method (2). In the absence of data on bone specific activity in infants and children we shall continue to designate the quantity of sodium measured by our method as total "exchangeable sodium."

Change in total body sodium with age. In Table III are listed data from the literature in regard to the direct chemical analyses of 33 fetuses and newborns for sodium. The progression of values for total body sodium is in the same direction as we found it to be in infants and children; except for the three youngest fetuses, total body sodium declines steadily, on a per kilogram basis, with advance in fetal age.

All of the data available on total body sodium have been combined in Figure 1 in which the sodium content, in meq. per Kg., is plotted against age for an age range from the third month of fetal life to the 34th year of post-natal life. Sodium content is quite low during the early months

of fetal life (34–50 meq. per Kg.), but rises rapidly to a maximum (94–118 meq. per Kg.) in the five month fetus, after which it falls, at first quite rapidly, later more slowly, to adult values at about the time of puberty. Interestingly enough, adult values are quite similar to those noted for the two youngest fetuses. We had thought at one point in our investigations that experimental error might be responsible for the rather wide range of values noted in our supposedly healthy subjects; the spread in values reported for direct carcass analysis, a method which should be less subject to experimental error than is the isotopic dilution one, was reassuring.

Relation of total body sodium to body weight. Organization of the available data on total body sodium (Tables I and III, and Table I of reference 2) is achieved by plotting sodium content against weight on a double logarithmic grid. Values obtained by direct chemical analysis (from the literature) are illustrated in Figure 2. Two regression equations are necessary to describe sodium growth from the third month of fetal life to birth; calculated by the method of least squares, these

are, for the 18–115 Gm. fetus:

$$\log \text{Na content, meq.} = 1.51 \log \text{weight, Gm.} - 2.044.^6 \quad (1)$$

or in exponential form

$$\text{Na, meq.} = 0.00904 \text{ Gm.}^{1.51}$$

and for the 259–3360 Gm. fetus:

$$\log \text{Na} = 0.832 \log \text{weight} - 0.537 \quad (2)$$

or

$$\text{Na} = 0.290 \text{ Gm.}^{0.832}$$

Whether the change in slope from equation 1, indicating that sodium content of the fetus is increasing rapidly on a per kilogram basis, to that of equation 2, in which the reverse obtains, is abrupt or gradual cannot be ascertained from the data at hand.

Data for post-natal life, obtained by the isotopic dilution method, are plotted in a similar manner in Figure 3. The regression equation for in-

⁶ Logarithms to the base 10.

FIG. 1. PLOT OF SODIUM CONTENT, MEQ. PER KG., AGAINST AGE IN YEARS

○ = fetus, total body sodium by direct chemical analysis (Table III). Infants, children, and adults, TES by isotopic dilution (Table I and Table I of reference 2): ● = males, × = females.

infants,⁷ children and adult males is strikingly similar to that calculated for the older fetuses. The following equation fits these data quite well over a weight range of 1795–100,000 Gm.:

$$\log Na = 0.829 \log \text{weight} - 0.552 \quad (3)$$

⁷ With one exception, all of the infants in our series were males. The single female infant was so far removed from the main group of female subjects (Table I) that its inclusion in the regression calculations for females would weight the resulting equation rather heavily in its favor; it was therefore grouped with the males.

or

$$Na = 0.281 \text{ Gm.}^{0.829}$$

For females between 23,800 and 81,600 Gm. in weight, the equation is

$$\log Na = 0.754 \log \text{weight} - 0.234 \quad (4)$$

or

$$Na = 0.584 \text{ Gm.}^{0.754}$$

The various statistical constants for these equations are listed in Table IV. In view of the

FIG. 2. LOG-LOG PLOT OF TOTAL BODY SODIUM AGAINST WEIGHT FOR THE HUMAN FETUS

Data from Table III. Regression lines drawn according to equations 1 and 2. The dotted lines represent one standard deviation from regression.

FIG. 3. LOG-LOG PLOT OF TES AGAINST WEIGHT FOR INFANTS, CHILDREN, AND ADULTS

Data from Table I and Table I of reference 2. Regression lines drawn according to equations 3, 4, and 6. Dotted lines represent one standard deviation from regression (equation 3). Notice that the lower half of the right-hand vertical scale has been changed to allow for inclusion of the regression line for equation 6. ● = males, ○ = females.

small number of observations, they are omitted for equation 1.

That there is an orderliness to chemical growth is immediately apparent; furthermore, the growth pattern can be expressed by a simple exponential equation, and it does not seem to be necessary to resort to more complicated expressions such as the quintic used by Mitchell and associates (13) to describe calcium growth in the human. The regression lines described by equations 2 and 3 are vir-

tually parallel, and extrapolation of either one would cause it to lie within one standard deviation of the other over the range of body weights under study. Log-log plots of sodium content against height and surface area were also made, but the fit of the data (by inspection) was no better than that using weight. Logically, weight is to be preferred over height or surface area as a basis of reference, since weight and sodium are both measured in mass units.

TABLE IV

Subjects	Number	Weight range, Gm	k	Standard error of k	Standard deviation of regression	Correlation coefficient
Fetuses (equation 2)	29	259-3360	0.832	0.027	0.047	0.988
Infants, children and adult males (equation 3)	49	1795-100,000	0.829	0.015	0.057	0.992
Females (equation 4)	9	23,800-81,600	0.754	0.007	0.028	0.972

Despite the smooth trend of the data, attested by the excellent correlation coefficients (Table IV), they are not sufficient to allow formal statistical comparison between the various regression equations. The data are not distributed homogeneously within each group, and the range covered by the female data (equation 4) is too small. The largest group of subjects are described by equations 2 and 3, whose slopes are almost parallel; yet the two regression lines overlap during only a small part of the total growth period (1795–3360 Gm.).

Characterization of total body sodium by means of a constant differential growth ratio. Extrapolation of the fetal data (equation 2) to cover the range represented by adults (equation 3) is certainly unwarranted on a statistical basis, yet the similarity between the two regression coefficients is of considerable interest.

The data suggest very strongly that a constant differential growth ratio characterizes sodium "growth" in man from mid-fetal life to maturity. First used a half-century ago to relate brain weight to total body weight (*vide* Brody [14] pp. 605–609), the concept of relative growth rates was expanded by Huxley (15) and shown to apply to individual organ weights and lengths in a number of species. Brody (14) demonstrated that the concept could be extended beyond the realm of morphology to include a number of physiological functions, while Needham (16) called attention to the fact that chemical growth could also be characterized in this way. The general equation is an exponential one, $y = bW^k$. Using symbols appropriate to this report we have

$$Na = bW^k \quad (5)$$

where Na is total body sodium or total "exchangeable sodium" in meq. depending on which of the foregoing equations are used, and W is body weight in Gm. The general equation states, in essence, that the specific growth rate of an organ or in this instance a body constituent, $\frac{1}{Na} \cdot \frac{dNa}{dt}$, is directly proportional to the specific growth rate of the body as a whole, $\frac{1}{W} \cdot \frac{dW}{dt}$.⁸

⁸ *Specific growth rate* is defined as the rate of change of log body size with respect to time, $\frac{d(\log W)}{dt}$, in contrast to *simple growth rate*, $\frac{dW}{dt}$.

The close fit of the data noted in Figures 2 and 3 indicates that equation 5 can be used to describe the process of chemical growth in man quite nicely, and consequently that the rate of sodium accumulation per unit total body sodium is directly proportional to the rate of increase in body weight per unit weight during growth. The exponent k , which is independent of the units of measurement employed, is the ratio of differential growth. The data presented in this report indicate that k is constant in the human organism between weights of 250–100,000 Gm.

Equation 5 states that body sodium content does not vary directly with simple body weight but with body weight raised to the k th power. Brody proposed that W^k be designated "physiological weight" or "metabolically effective weight" in contradistinction to $W^{1.0}$ which is body mass or gravitational weight. Total body sodium increases during growth as a constant fractional power of body weight: in terms of *per cent change*, body sodium content increases by only 83% for each 100% change in weight. A consideration of equations 2 and 3 indicates that this "fundamental chemical plan of animal growth" (16) is in operation over most of the span of human growth.

Data on total body sodium content have been reported for the chick embryo (17) and for the young rat (18). The ratio of differential growth, k , remains constant in the chick embryo at the value of 0.94 between four and 21 days of incubation, and for the rat at 0.812 over the period studied, from birth to 28 days.⁹ The latter ratio is very close to that for the human; it is unlikely, therefore, that the demonstrated mathematical relationship between sodium content and body weight in man is a fortuitous one. Although objections have been raised to the use of such a simple mathematical expression for describing growth (19), it has proved very useful in interpreting a variety of growth phenomena in different species and in providing a basis for interspecies comparison (14).

A comparison of the regression equations for fetuses (equation 2) and for infants, children, and adults males (equation 3) suggests that there may be systematic error in the isotopic dilution method for determination of total body sodium in that

⁹ The value of k was determined by inspection in the case of the chick data and by calculation for the rats.

values appear to be slightly lower than would be predicted from extrapolation of data obtained by direct chemical analysis. If it is assumed that a comparison between these two equations is warranted, mean values for total "exchangeable sodium" represent 93% of total body sodium in the infant of 3000 Gm. and 91% of the total sodium in the 100 Kg. adult male. The close similarity of the regression coefficients for equations 2 and 3 in some degree justifies the extrapolation of the fetal data; however, the question of the exact magnitude of the relationship of TES to the actual amount of sodium in the body cannot be settled until complete carcass analyses have been made in the older child and adult.

Predicted values for total "exchangeable sodium." The equations presented above allow one to predict the mean value for sodium content for any group of individuals of given weight. Total body sodium can be predicted for the human fetus 18 Gm. or more in weight by the use of equations 1 and 2, and total "exchangeable sodium" in post-natal life for subjects whose body weights are between 1800 and 100,000 Gm. in weight by substitution in equation 3 and 4.

The mean content of sodium, in terms of meq. per Kg. body weight, can be calculated directly if equations 1-4 are written in a slightly different way. Using equation 3 as an example, and converting to kilograms, we have

$$\text{meq. Na (TES)/Kg.} = 281 \text{ weight, Gm.}^{-0.171} \quad (6)$$

A plot of equation 6 is included in Figure 3, from which can be read directly the mean total exchangeable sodium, meq. per Kg., for any given body weight from 1795 to 100,000 Gm. There is, therefore, a steady and predictable decline in sodium content per unit weight during growth. Our data are not sufficient to permit statements as to the magnitude of the deviation from this curve which could be considered abnormal for any given subject.

The sodium increment of normal growth. Differentiation of the relative growth equation, $\text{Na} = bW^k$, with respect to weight, yields the following:

$$d(\text{Na})/dW = k \text{ Na}/W \quad (7)$$

The rate of change of sodium content with respect to weight is therefore a function of the amount of sodium in the body, in terms of meq. per unit

weight, and would be expected to decline as growth proceeds since k is less than unity. From this equation the *instantaneous* rate of change in body sodium per unit body weight *gain* can be calculated for any given body weight. As a result, one can anticipate the sodium increment due to normal growth from a knowledge of initial weight and weight gain provided the observational period is not too long. For example, an infant of 4000 Gm. (predicted sodium content 0.068 meq. per Gm.) would be expected to retain $0.068 \times 0.829 = 0.056$ meq. of sodium for each gram of weight gain as a result of normal accumulation of new body tissue. A gain of 20 Gm. in body weight on this particular day of observation would therefore lead to a positive sodium balance of 1.1 meq. Perhaps calculations done in this way could be of some use in the interpretation of balance studies.

Correlation of total sodium content with other body components. A number of organ weights in man have been related to total body weight by the use of the relative growth equation (Brody [14], p. 584). One can therefore calculate the relative growth rate of a given body component in terms of a second component in the way suggested by Adolph (20).

The importance of the kidney in body sodium economy is brought out most clearly by this sort of approach. During post-natal life of all the organs listed for man, only kidney weight changes as the 0.83 power of body weight, the equation being $y = 0.00892 W^{0.83}$, where y and W stand for kidney weight and total body weight, respectively, in grams. Since total body sodium (or TES) also changes as the 0.83 power of body weight during growth, there is an arithmetic relationship between kidney weight and the amount of sodium in the body. Division of equation 3 by the equation for the kidney weight yields the following:

$$\frac{\text{TES, meq.}}{\text{kidney weight, Gm.}} = \frac{0.281}{0.00892} = 31.5$$

which suggests that each gram of kidney tissue supports in the body economy about 31.5 meq. of "exchangeable" sodium. Renal function *per se* is not considered here; rather it is the relation of absolute kidney weight to the amount of sodium present in the body. The ratio is applicable (at least in males) over a large range of body weight. While this type of mathematical approach does not

constitute proof of the suggested relationship between sodium content and kidney size, it does serve to emphasize further the intimate role of the kidney in sodium metabolism. Data for the mass of two other body components concerned in sodium metabolism, namely, skeleton and muscle, unfortunately are not available for comparison with total sodium content in this way.

SUMMARY

1) Measurements of total "exchangeable sodium" (TES) were made in a series of 21 infants and children by the isotopic dilution method, using radiosodium²⁴. The subjects ranged in weight from 1795 to 56,800 Gm.

2) A comparison of the data for young infants with carcass analyses reported in the literature indicates that the two methods for determining total body sodium give comparable results.

3) Values for TES are highest in the young infant, averaging 70 meq. per Kg. in the 3300 Gm. newborn and gradually decline in a curvilinear fashion with age until adult values are reached (approximately 42 meq. per Kg.).

4) When all of the available data on total body sodium (TES data from this report and that of the preceding report [2] together with carcass analyses from the literature) are brought together, a straight line relationship results when sodium content is plotted against body weight on a double logarithmic grid.

5) Total body sodium thus conforms to the relative growth equation, $Na = bW^k$, from mid-fetal life to maturity. Regression equations have been calculated which allow mean values of total body sodium or TES to be predicted for any given weight.

6) Treatment of the data in this way suggests several tentative conclusions:

a) Total sodium changes with body weight in a predictable systematic fashion, namely, as a fractional power of body weight, and behaves as a constant differential growth ratio.

b) Predictions of the sodium retention occurring as a result of normal growth can be made for any given weight.

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