

# THE DAILY RATE OF GROWTH OF TOE NAILS

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## INTRODUCTION

It is generally known that nail growth is often retarded in acute infectious diseases, such as various fevers. However, no work has been published concerning the quantitative effect of disease and other nutritional disturbances, such for example, as pregnancy and hyperthyroidism, on the rate of nail growth. Such a study is now in progress and a prerequisite step to this project was the determination of the normal rate of nail growth in healthy individuals.

Several workers, notably Berthold ('50), Dufour ('72), Heller ('00), Voit ('30) and Sharpey-Schäfer ('30), have studied the rate of growth of finger nails and although different methods of measurement were employed it is generally agreed that normally the growth is on the average of one millimeter in ten days, that is 0.100 mm. daily. Results of observations made by the writers on the daily rate of finger nail growth in a great number of normal, healthy subjects agree in general with this figure. As regard the rate of toe nail growth, however, a review of the literature has failed to reveal any published data. Since the need for such information was felt in connection with the problem concerning the effect of disease on the rate of nail growth, accordingly research was started in an attempt to supply it. The object of this paper, therefore, is to report the results of observations made on the daily rate of toe nail growth in 70 apparently normal, healthy subjects of both sexes, ranging in age from 3 to 65 years.

It has been found by several of the above mentioned investigators that numerous factors affect the rate of growth of finger nails. Thus according to Berthold they grow more rapidly in summer than in winter, in children than in adults and slowest in old age; that normally those on the right hand grow more rapidly than those on the left and most rapidly on the longest fingers and slowest on the thumbs. In view of these findings of Berthold et al it was also decided to investigate some of these

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factors with respect to toe nails. The 70 subjects were therefore subdivided into groups according to sex (33 males and 37 females) and age. Age groupings were arbitrarily made; children (20) including those up to the age of 15 years; youths (30) those from 16 to 25 years, and adults (20) all those 26 years or older. Comparison of the mean rates of toe nail growth of these groups as well as those of the various toes was made in order to determine whether or not there is any significant variation. The technique of analysis of variance was applied to the sample as a means of procedure. This directly brings out the elements that may be contributing to disturbed homogeneity.

#### METHODS

A mark was made on each toe nail by means of a sharp, curved scalpel. In the case of the great toe nails the mark was made at the distal central convex line of the lunula, whereas, on the remaining toe nails, from which a lunula is almost invariably absent, it was made at a determined distance, usually five millimeters, proximal to the anterior central border of the nail bed. The amount of growth exhibited by the great toe nails was determined by measuring the distance which the mark traversed from the anterior margin of the lunula, while in the case of the other toe nails it was calculated by subtracting the distance between the mark and the anterior border of the nail bed from the distance between the latter point and the mark used as a measuring point. Thus if the mark was made at a point 5 mm. from the anterior border of the nail bed and at a later date it was 3.5 mm. from the latter point the amount of growth would be (5 mm. minus 3.5 mm.) 1.5 mm.

The daily rate of growth of the nail was ascertained by dividing the amount of growth by the number of days of growth. Thus let us suppose that in 30 days of growth the distance of the mark from the lunula on the great toe nail was 1.5 mm. The daily rate of growth in this case would be (1.5 mm. divided by 30 days) 0.05 mm. For the other toe nails the method of calculation would be the same, that is (5 mm. minus 3.5 mm.) 1.5 mm. divided by 30 days (0.05 mm.).

All measurements were made by means of a Vernier caliper calibrated in millimeters, the two measuring arms of which were sharpened in order to insure a fine degree of accuracy. All marks on the nails as well as the adjustments of the measuring arms of the Vernier to these marks were made under magnification with the use of a binocular loupé.

#### RESULTS

In Table I are listed the data for the 70 subjects including the daily rate of growth of each toe nail (indicated as R and L 1-5, respectively), the age, sex and mean daily rate of nail growth for each subject and for each nail. The figures indicating the rates of nail growth represent thousandths of a millimeter. Thus in subject H. A., for example, the

TABLE I  
DAILY RATE OF GROWTH OF TOE NAILS  
Seventy Subjects

Subject	R1	2	3	4	5	L1	2	3	4	5	Age	Sex	M
H. A. ....	61	37	50	50	50	61	50	48	37	50	8	M	49.4
P. B. ....	52	56	48	50	50	53	48	57	48	32	20	M	49.4
P. B. ....	72	33	66	66	50	55	66	50	83	45	22	M	58.6
H. B. ....	50	20	10	50	52	27	35	20	19	51	20	M	33.4
M. B. ....	50	50	50	50	50	66	30	50	66	45	15	F	50.7
B. B. ....	56	50	50	50	66	55	33	53	66	53	10	F	53.2
E. B. ....	50	46	25	50	75	90	75	50	48	50	35	F	55.9
H. B. ....	50	50	50	50	50	66	50	50	50	50	39	F	51.6
I. B. ....	56	56	56	56	31	56	56	56	56	31	41	F	51.0
B. B. ....	66	50	66	66	50	66	50	66	66	45	14	M	59.1
R. B. ....	66	50	50	83	83	66	50	50	50	45	44	M	59.3
T. B. ....	70	58	58	60	50	60	59	30	40	45	25	F	53.0
J. C. ....	56	50	50	50	50	85	50	50	50	50	5	M	54.1
B. C. ....	75	50	50	50	50	75	62	50	50	50	8	F	56.2
P. C. ....	75	62	50	50	50	50	62	50	50	50	3	F	54.9
M. C. ....	62	50	50	37	37	62	50	37	37	50	10	F	47.2
V. C. ....	75	75	75	50	50	55	50	50	50	50	32	F	58.0
J. C. ....	62	50	50	50	50	62	50	50	50	50	6	F	52.4
I. D. ....	50	33	40	30	50	46	50	50	50	45	15	F	44.4
M. D. ....	66	40	50	33	50	50	50	50	50	50	26	M	48.9
L. E. ....	50	50	50	50	50	50	50	50	50	45	34	M	49.5
A. E. ....	57	57	57	57	57	57	57	57	57	57	58	M	57.0
F. E. ....	57	57	57	50	50	57	57	57	48	45	28	F	53.5
E. E. ....	50	50	50	50	50	66	50	50	50	66	28	F	53.2
A. E. ....	56	50	57	50	50	57	57	57	48	45	55	F	52.7
M. E. ....	56	50	25	25	50	75	75	25	48	45	62	F	47.4
B. E. ....	60	60	60	60	60	70	50	30	70	45	19	F	56.5
L. G. ....	66	59	48	58	39	64	63	48	32	42	20	M	51.9
J. G. ....	70	50	50	50	50	55	50	50	50	50	6	F	52.5
C. G. ....	62	50	50	50	50	62	50	50	50	50	8	F	52.4
A. H. ....	50	50	48	83	50	30	66	56	66	50	26	M	54.9
M. H. ....	50	50	50	50	50	50	50	50	50	50	30	F	50.0
L. H. ....	66	40	53	36	43	66	50	50	53	40	6	F	49.7
J. H. ....	37	25	25	25	50	37	37	37	50	45	65	F	36.8
R. J. ....	50	66	66	66	83	50	66	66	83	66	23	M	66.2
G. K. ....	66	45	45	66	66	45	66	66	45	30	25	F	54.0
W. K. ....	58	27	33	40	26	49	39	36	43	45	21	M	39.6
H. K. ....	50	33	29	38	50	48	48	38	46	36	19	F	41.6
G. K. ....	58	49	69	42	40	52	42	58	50	45	20	M	50.5
M. K. ....	40	57	40	38	50	55	57	57	56	45	19	F	49.5
H. L. ....	59	54	38	14	40	51	40	35	48	45	20	M	42.4
M. L. ....	60	53	53	73	83	58	53	62	62	73	20	M	63.0
B. L. ....	44	32	44	56	47	36	42	47	53	42	18	F	44.3
S. M. ....	35	50	50	50	35	35	50	50	50	25	20	F	43.0
B. M. ....	50	51	50	50	25	50	50	50	51	25	21	F	45.2
E. M. ....	86	40	65	65	65	65	50	50	50	25	19	F	56.1
E. M. ....	60	30	30	30	30	75	30	60	30	30	21	M	40.5

TABLE I—[Continued]

Subject	R1	2	3	4	5	L1	2	3	4	5	Age	sex	M
L. M. ....	46	28	40	50	50	36	41	54	33	45	19	F	42.3
H. M. ....	48	26	35	50	50	47	58	58	58	29	30	M	45.9
P. M. ....	75	50	50	50	37	75	62	37	50	37	19	F	52.3
H. P. ....	43	33	40	59	33	50	50	50	50	40	16	F	44.8
R. P. ....	66	66	66	66	50	73	66	50	66	66	14	F	63.5
B. P. ....	33	50	33	33	50	50	33	50	33	33	10	F	39.8
D. R. ....	34	34	44	48	44	48	50	50	50	48	16	F	45.0
S. R. ....	75	55	55	65	25	50	65	60	65	25	19	M	54.0
J. R. ....	77	44	46	81	50	74	38	55	48	45	22	M	55.8
H. S. ....	40	40	40	40	40	40	40	40	40	40	60	F	40.0
A. S. ....	56	45	45	45	45	45	30	45	30	45	59	M	43.1
H. S. ....	90	46	30	53	50	55	18	23	30	45	34	M	44.0
W. S. ....	66	50	66	33	50	40	33	33	50	66	30	F	48.7
M. S. ....	47	37	53	54	50	50	24	45	54	60	21	F	47.4
H. S. ....	50	50	53	50	83	50	50	50	40	50	8	M	52.6
J. S. ....	40	32	52	50	50	47	38	38	57	35	22	M	43.9
R. S. ....	47	53	67	70	50	46	36	60	49	40	22	M	51.8
M. W. ....	52	38	38	45	38	56	38	47	45	52	28	M	44.9
D. W. ....	40	66	66	66	66	66	33	40	46	50	4	M	53.9
D. W. ....	50	50	50	50	50	66	66	66	66	66	7	M	58.0
D. W. ....	65	45	40	60	60	75	25	48	20	45	24	M	48.3
R. Y. ....	50	50	50	50	50	50	50	50	50	50	3	M	50.0
P. Y. ....	50	33	60	33	50	33	33	50	50	33	6	M	42.5
Means...	56.6	46.7	48.6	50.7	50.0	55.6	48.5	48.6	49.7	45.5			50.1

daily rate of growth of the great toe nails (R and L 1) is 61 thousandths of a millimeter each, which should be translated to read 0.061 mm. and the mean rate of growth of all his toe nails (49.4 thousandths of a millimeter) as 0.0494 mm.

The mean daily rate of growth of each nail is shown in the last horizontal line of figures at the bottom of the table, each figure representing the mean daily rate of growth of 70 toe nails. The last figure (50.1) on this horizontal line is the mean daily rate of growth of all the toe nails of the whole group, that is, of 700 toe nails (70 subjects  $\times$  10 toe nails). The mean daily rate of growth per toe nail then can be stated as .050 mm. with its standard error = .0046.

Since the rate of growth of toe nails in relation to that of finger nails in healthy individuals is a pertinent question, the average rate of toe nail growth can be said in general to be approximately half that of the finger nails, that is .050 mm. for toe nails as to .100 mm. for finger nails.

However, the whole set of observations on the rate of growth of toe nails can not be considered as strictly homogeneous, since there is considerable variation from toe to toe and from individual to individual. If these variations are subjected to analysis of variance (Snedecor, '34) several interesting features regarding their source are brought out. From the figures given in Table II the homogeneity of the several toe

means is examined by the ratio of the greater mean square to the lesser mean square. Designating this ratio by F,

$$F = \frac{\text{large mean square (869.95)}}{\text{smaller mean square (106.87)}} = 8.14$$

When this F ratio is referred to the table for an expression of the probability (Snedecor, pp. 88-91) it is found that the F of 8.14 lies beyond the 1% range expressed by an F of 2.55. That is, any variation as great as that observed would be expected to occur less than once per hundred samples if random variation alone were the sole source of differences.

TABLE II  
ANALYSIS OF VARIANCE BETWEEN TOES AND INDIVIDUALS

Source of Variation	Degrees Freedom	Sum of Squares	Mean Square	Standard Deviation
Total.....	699	103,171.80		
Between Means of Toes....	9	7,829.56	869.95	
Between Means of Individuals.....	69	28,977.50	419.96	
Remainder.....	621	66,364.74	106.87	10.3380

In order to determine which toe nails differ significantly in their rate of daily growth the standard error of difference between toe means was calculated as follows:

$$\sqrt{\frac{(106.87) (2)}{70}} = \sqrt{3.0534} = 1.7474 \text{ thousandths of 1 mm.}$$

Corresponding to the 5% point for 500 degrees of freedom, the value of t = 1.965 (table XXXV, Snedecor). Therefore, the least mean difference that can be considered significant is (1.965) (1.7474) = 3.434 thousandths of 1 mm.

Any difference between any two toe means, listed in Table III, that is greater than 3.434 thousandths of 1 mm. can be taken as indicative of a real difference. Reading the table for complete comparisons it is evident that the rate of growth of the great toe nails is distinct from the rates of the others. In general, the nails of the 2nd, 3rd, 4th and 5th toes tend toward homogeneity in growth rate. However, some tendency toward irregularity is introduced into this grouping by the somewhat retarded growth of the left 5th toe.

In order to determine whether or not the variation in the mean rate of toe nail growth between individuals is contributing significantly to the heterogeneity of the sample, the F ratio is applied to the figures in Table II. The ratio is the larger mean square, that between means of individuals, to the remainder, or uncontrolled variation, namely, 419.96 to 106.87. Thus:

$$F = \frac{419.96}{106.87} = 3.93$$

When this ratio is compared with the values 1.54 and 1.83 for the 5% and 1% limits of significance (Snedecor, table XXXV) the value of F therefore indicates lack of homogeneity. That is, the mean daily rates

TABLE III  
DIFFERENCES BETWEEN VARIOUS TOE MEANS

	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
R1.....										
R2.....	9.87									
R3.....	7.97	1.90								
R4.....	5.84	4.03	2.13							
R5.....	6.56	3.31	1.41	0.71						
L1.....	1.00	8.87	6.97	4.84	5.56					
L2.....	8.07	1.80	0.10	2.23	1.51	7.07				
L3.....	7.93	1.94	0.04	2.09	1.37	6.93	1.40			
L4.....	6.83	3.04	1.14	0.99	0.27	5.83	1.24	1.10		
L5.....	11.06	1.19	3.09	5.21	4.50	10.06	2.99	3.13	4.23	

TABLE IV  
TOE MEANS BASED ON AGE CLASSIFICATION

		1	2	3	4	5	Mean	Standard Error
70.....	(R	56.6	46.7	48.6	50.7	50.0		
	L	55.6	48.5	48.6	49.7	45.5		
	M	56.1	47.6	48.6	50.2	48.7	50.1	± .46
Male (33).....	(R	57.5	45.6	48.3	54.3	55.4		
	L	54.1	48.5	48.8	49.8	46.5		
	M	55.8	47.0	48.5	52.0	50.9	50.9	± .70
Female (37).....	(R	55.7	47.6	48.9	47.7	47.4		
	L	55.2	49.7	47.2	50.1	44.6		
	M	55.4	48.1	48.0	48.9	46.0	49.4	± .57
Children 1-15 yrs. (20)	(R	57.6	49.3	51.8	48.3	52.6		
	L	60.4	48.4	50.5	51.3	49.4		
	M	59.0	48.8	51.0	49.8	51.0	51.9	± .73
Youths 16-25 yrs. (30)	(R	56.7	44.1	47.9	53.3	47.1		
	L	53.2	47.7	48.5	49.5	39.0		
	M	54.9	45.9	48.2	51.4	43.0	48.7	± .41
Adults 26+ yrs. (20)	(R	55.5	48.2	46.3	49.5	51.3		
	L	54.6	49.8	47.0	48.7	48.6		
	M	55.0	49.0	46.6	49.1	49.9	49.9	± .85

of toe nail growth from individual to individual varies significantly and is not wholly attributable to errors in random sampling. Calculating the standard error of the difference between any pair of means

of individuals by the same method as used for that between toes, any mean difference as great as or greater than 9.08 thousandths of 1 mm. can be considered as having contributing causes aside from the variation expected in random sampling.

In Table IV are tabulated the relative mean differences with their standard error of the age and sex subgroups as compared with the total group. The lack of homogeneity of nail growth between individuals is not attributable to age differences for there is almost complete lack of correlation between age and mean growth rate. The observed correlation is  $-0.12$ , and a correlation of that size might occur in at least 30% of the samples drawn from an uncorrelated population. Moreover there are no sex differences relative to toe nail growth as far as this sample is concerned, since the mean difference between daily rates of males and females is  $1.4 \pm .8992$  thousandths of 1 mm.

TABLE V  
PROBABILITIES OF MEAN DIFFERENCES BETWEEN AGE CLASSES

	Y <sub>1</sub>	Y <sub>2-5</sub>	A <sub>1</sub>	A <sub>2-5</sub>
C <sub>1</sub> .....	.09	.....	.14	.....
C <sub>2-5</sub> .....	.....	.01	.....	.54
Y <sub>1</sub> .....	.....	.....	.96	.....
Y <sub>2-5</sub> .....	.....	.....	.....	.45

However with reclassification into age groups (children 1-15; youths 16-25; adults 26+) and toe groupings, which combine the great toes in one class and the remaining toes in another, certain differences are brought out. When the mean differences are compared in terms of their standard errors and then expressed in terms of their relative probabilities, a summary tabulation, Table V, brings out the following points: the differences between the mean growth rate of the great toe nails do not depart radically from homogeneity in the age classification. The only point of real difference is between the rate of nail growth of the small toes of children and youths, here expressed by the value of .01, meaning that a mean difference as large as that observed (2.91) could occur only once per hundred times if random sampling alone contributed to the variation.

Since the great toes throughout all classifications give a more uniform measure of nail growth than the remaining toes considered as a group, it seems justifiable to use their mean rate as a standard against which to judge abnormal rates of growth. The mean rate of growth of the great toe nails here is 56.1 thousandths of 1 mm. with a standard deviation 12.3. Then, any individual whose daily rate of growth in the great toe nails exceeds 80.7 thousandths of 1 mm. ( $56.1 + 2\sigma$ ) or was less than 31.5 thousandths of 1 mm. ( $56.1 - 2\sigma$ ) could be considered as outside the range of normal growth.

The authors wish to acknowledge valuable assistance rendered by Mrs. Wilma B. Setterfield during the progress of this study.

## SUMMARY

1. The mean daily rate of toe nail growth of the 70 apparently normal individuals used in this study was observed to be 50.1 thousandths of 1 mm.
2. The mean daily rate of toe nail growth on corresponding toes does not differ significantly.
3. The mean daily rate of growth of the nails of the great toes, however, is distinctly greater than the rate of the other toes, and for purposes of comparison it is suggested that this difference is worthy of account.
4. Age and mean individual rates showed no significant correlation in the observed sample.
5. There are no sex differences relative to rate of toe nail growth.
6. Age and subclassification into great and remaining toes showed that the most extreme difference in rate of toe nail growth was between the small toes of children (1-15 yrs.) and of youths (16-25 yrs.).

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