Intelligence of Troops Infected with Hookworm vs. Those not Infected

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History and Procedure

During the War, Major B. F. Pittenger, Sanitary Corps, chief psychological examiner at Camp Sevier, in collaboration with Major Charles A. Kofoid, Sanitary Corps, in charge of the Laboratory Car Metchnikoff, made a study of the comparative intelligence ratings of the recruits found to have hookworm infection and those without infection, of the 9,254 men of the April, 1918, draft increment. A report thereon to the Office of the Surgeon General, Division of Psychology, was made by Major Pittenger in comparative tables for hookworm and non-hookworm groups, respectively, in terms of Alpha and Beta scores, for white and for colored troops. Of these data Major Charles A. Kofoid and Lieutenant J. P. Tucker, Medical Corps, offer some interpretation in their report to the Laboratory Division of the Surgeon General's Office "on the relationship of infection by hookworm to the incidence of morbidity in 22,842 men in the United States Army at Camp Bowie, Texas, from October, 1917, to April, 1918."

The manifest inferiority of the median intelligence scores of the 762 hookworm cases to the 8,492 non-hookworm cases suggested the desirability of a more comprehensive study wherein each hookworm case could be paired with a non-hookworm case from the same local community. Accordingly Major Kofoid recommended to the Surgeon General a co-

operative study of the problem by the Laboratory Division and the Section of Psychology. A psychological officer was not immediately available, but Major John L. Riley, Sanitary Corps, was released by the Section of Physical Reconstruction for temporary duty with Major Kofoid in organizing and promoting the early work of this investigation. Under their direction a group of officers, laboratory technicians and enlisted men proceeded to assemble and to code for Hollerith treatment the intelligence ratings of recruits infected with hookworm and of their non-infected pairs.

During the second week in July, 1919, Captain Garry C. Myers of the psychological personnel became available for duty on this investigation. He reported to the Surgeon General to select and ship records from the files of the Section of Psychology to the Port of Embarkation, where initial work was already in progress. A week later he was ordered to U. S. A. Laboratory, Port of Embarkation, New York City, for duty in connection with the statistical treatment of the records.

The personnel at the laboratory, in charge of Lieut. Col. Edwin H. Schorer, varied from seventeen officers, enlisted men and women during July and early August to five officers and assistants in early September. Different officers from time to time awaiting their discharge were assigned for but a few days, whereas Second Lieutenant Conrad Erwin Ronnenberg, Sanitary Corps, and Lieutenant Henry S. Weigle, Medical Corps, were indispensable collaborators throughout the whole period of the work at the port of embarkation.

Major Kofoid left the service on August 8th and Major Riley left the service on September 6th, leaving the work in charge of Captain Myers, who again reported at the office of the Surgeon General on September 10th to complete the study. Upon his arrival, it was found that inordinate demands upon the statistical department eliminated all hope of final Hollerith tabulation of the data and it appeared that completion of the study would have to be postponed indefinitely. However, through the interest and initiative of Colonel Joseph F. Siler, Medical Corps, of the Laboratory Division and Colonel F. F. Russell, Medical Corps, of the Army Medical School, two enlisted men were assigned to assist Captain Myers in assembling the data by the traditional method of hand tallying. Frequency tables were thus completed in about three weeks. Sergeant Benjamin M. Oppenheim was then loaned by the Division of Coordination, Organization and Equipment to plot the graphs.

Thus it will be perceived that Major Kofoid initiated the

study and the larger machinery for its execution; Major Riley supervised the greater portion of the work assembling the data for this study at the port embarkation; and Captain Myers is responsible for the final assembling and treatment of data with their interpretations.

The methods of pulling intelligence rating cards was as follows: Each time a card of a hookworm soldier was found, another card was paired with it, of a soldier, reported on hookworm rosters as not having hookworm, and whose home address was of the same county as that of the hookworm case with whose card it was paired.

The study was started with the hope to compare 10,000 hookworm cases paired with 10,000 non-hookworm cases from the same local areas in terms of home addresses. However, owing to the frequent disparity between the groups and organizations surveyed for hookworm and the groups and organizations surveyed by the intelligence rating boards (since the latter boards were organized in some camps subsequent to the earlier hookworm surveys) and to the absence of necessary data either from the hookworm rosters or from the intelligence rating cards, only 6,639 hookworm and 6,639 non-hookworm cases were studied, of which number of each there were 612 cases of colored troops.

In every instance where two or more examinations had been given, that score was counted which on the basis of the equivalent mental age scale as per the Psychological Examiner's Guide, page 91, gave the highest record. All Alpha and all Beta records were assembled in separate tables and all individual-tests records were merged with Alpha and Beta scores into a common scale on the basis of equivalent mental ages, which in turn were converted into equivalent letter ratings as per Examiner's Guide, page 91.

The statisticians[1] in the Section of Psychology of the Surgeon General's Office who had developed these mental age and letter rating equivalents to meet an urgent need during the war, had found in a later study that these equivalents were but roughly accurate. Consequently they, with the help of Karl Pearson, developed by an elaborate and exhaustive study the groundwork of very refined equivalents. However, these statisticians left the service before a table was developed applicable for this study. Certainly then the ratings of this study, which are indicated by the "Common Scale," are not so exact as they ought to be; yet they are the best which the available standards offered as expedient.

[1] Mr. Carl R. Brown and Lt. Mark A. May.

Is allowance made for heredity, mental training, environment and duration of infection? Should these be slighted?

In addition to the intelligence rating the chronological age and years of schooling were taken into account. Rank also was noted early in the study but because the intelligence record cards—as would be expected since they were taken soon after the recruits entered camp—listed practically all soldiers as privates, rank difference proved sterile for this study.

Furthermore, the record cards were pulled on the basis of "heavy territory" and "light territory," the former meaning a county in which the army hookworm survey indicated more than 10% of recruits infected with hookworm; the latter, less than 10% of recruits infected. In case, then, an intelligence record card was found of a soldier infected with hookworm, whose home address was in a light county, the intelligence record card of a non-hookworm soldier from the same county was pulled.

With the negroes, whose intelligence rating cards as well as hookworm survey rosters were sometimes designated as merely from Texas, say, or Tennessee, it was almost impossible to compare light territory and heavy territory groups. This fact, in addition to the relatively small number of cases, explains why the colored troops are limited to one general table of comparison of hookworm cases with non-hookworm cases.

RESULTS

TABLE I

PER CENT DISTRIBUTION OF RATINGS

All White Troops

	Alpha		Beta		Com. Scale	
	Hookworm	Non-hookworm	Hookworm	Non-hookworm	Hookworm	Non-hookworm
A	1.2	3.0	0.7	1.1	1.5	3.5
B	4.4	7.9	1.1	2.2	4.6	8.2
C+	11.5	16.6	2.2	4.2	7.3	10.9
C	26.9	29.6	10.6	14.1	23.7	27.4
C—	30.3	25.2	27.6	25.6	34.8	29.6
D	17.4	11.7	40.1	36.9	19.3	14.5
D—	8.1	5.8	17.4	15.7	8.5	5.9
			White Troops (Heavy Territory)			
A	1.1	2.6	0.6	0.9	1.3	2.9
B	4.8	7.4	0.9	2.1	4.6	7.3
C+	12.3	17.1	2.2	3.8	7.0	10.3
C	27.0	30.7	10.0	14.0	22.5	25.7
C—	30.7	24.8	27.9	26.0	34.8	29.7
D	16.8	11.3	41.9	38.2	21.0	16.5
D—	7.3	6.1	16.5	15.0	8.8	6.6
			White Troops (Light Territory)			
A	1.4	3.6	1.2	2.3	1.8	4.7
B	4.0	8.7	1.9	2.5	4.6	9.8
C+	10.4	16.0	2.3	6.0	8.1	12.1
C	26.8	28.1	12.9	15.0	26.2	28.7
C—	29.8	25.8	26.7	24.0	35.0	29.5
D	18.2	12.3	34.2	31.0	16.2	10.8
D—	9.4	5.5	20.8	19.2	8.0	4.4
			Colored Troops			
A	0.0	0.0	0.7	1.3	0.7	1.6
B	1.8	1.5	0.7	2.9	1.1	2.0
C+	1.8	3.5	1.4	3.6	1.0	2.8
C	6.2	10.4	5.2	5.2	5.0	7.2
C—	17.3	14.8	11.0	11.4	15.2	18.8
D	16.7	22.3	37.2	33.3	38.4	35.9
D—	56.2	47.5	43.8	42.2	38.6	31.7

TABLE II

MEDIANS OF HOOKWORM CASES VS. MEDIANS OF NON-HOOKWORM CASES

White Troops

	Alpha		Beta		Com. Scale (Mental Age)		Age (Chronol)		Schooling	
	Number	Median	Number	Median	Number	Median	Number	Median	Number	Median
	3546	40.5	2251	40.6	6027	12.26	5930	24.2	4456	6.1
	3940	51.4	1950	43.2	6027	13.00	5796	25.0	4597	6.7
		10.9		2.6		.74		.8		.6
		21.2		6.0		5.70		3.2		8.9
	2083	41.8	1731	40.6	3972	12.34	3911	24.3	3154	6.0
	2310	51.8	1596	42.8	3972	12.83	3860	25.1	3260	6.4
Hookworm Inferiority		10.0		2.2		.49		.8		.4
Per Cent Inferiority		19.3		5.1		3.8		3.2		6.2
Hookworm Light Territory	1463	39.3	520	40.5	2055	12.46	2019	23.9	1302	6.5
Non-Hookworm Light Territory	1630	50.8	354	44.8	2055	13.32	1936	24.8	1337	7.7
Hookworm Inferiority		11.5		4.3		.86		.9		1.2
Per Cent Inferiority		22.6		9.6		6.4		3.6		15.6

Colored Troops

Hookworm	162	12.6	290	23.8	612	10.04	600	23.7	340	3.5
Non-Hookworm	202	16.1	306	24.0	612	10.50	602	24.4	313	4.1
Hookworm Inferiority		3.5		.2		.46		.7		.6
Per Cent Inferiority		21.7		.8		4.4		2.9		14.6

TABLE III

AVERAGE NUMERICAL SCORE OF SUCCESSIVE TEN PER CENT STEPS FROM HIGHEST TO LOWEST.

All White Troops

	Alpha		Beta		Com. Scale	
	Hookworm	Non-Hookworm	Hookworm	Non-Hookworm	Hookworm	Non-Hookworm
1st (highest) ten per cent	111.7	128.9	80.4	87.2	16.7	17.5
2nd " " "	78.5	95.2	65.2	69.9	14.5	15.8
3rd " " "	63.3	78.2	54.6	61.5	13.6	14.6
4th " " "	52.7	65.4	49.1	53.3	12.9	13.7
5th " " "	44.1	55.4	43.1	45.7	12.3	13.1
6th " " "	36.5	46.4	35.9	39.3	11.7	12.4
7th " " "	30.3	38.8	29.0	33.4	11.2	11.8
8th " " "	24.2	30.2	23.8	25.2	10.6	11.1
9th " " "	18.8	22.6	17.8	19.1	9.8	10.2
10th " " "	10.5	12.2	8.0	8.1	8.6	8.9
Colored Troops						
1st (highest) ten per cent	71.1	80.2	74.6	86.3	14.6	16.1
2nd " " "	35.9	44.6	49.4	61.5	11.5	12.5
3rd " " "	25.7	29.8	35.4	45.2	10.6	11.3
4th " " "	19.2	21.8	31.1	34.4	10.0	10.6
5th " " "	14.0	17.3	26.0	27.2	9.9	10.1
6th " " "	11.5	13.1	20.1	21.0	9.5	9.7
7th " " "	6.9	9.9	14.4	16.2	9.0	9.4
8th " " "	6.4	6.7	10.6	12.2	8.7	8.9
9th " " "	2.0	2.0	7.0	6.9	8.3	8.5
10th " " "	2.0	2.0	2.2	3.5	7.4	7.7

Table I shows the comparative distribution by letter ratings of hookworm and non-hookworm groups for Alpha, Beta and "Common Scale," for all white troops, for white troops of light territory and of those of heavy territory, and for all colored troops. Median numerical scores for Alpha and for Beta, median mental age (Common Scale), median chronological age and median number of years attending school are given under corresponding legends in Table II. These distributions of ratings of ages and years of schooling with their respective medians are all presented graphically in plates 1-22.

Furthermore, all the hookworm troops are compared with all the non-hookworm troops in respect to successive 10% increments in Alpha, Beta and "Common Scale," as shown in plates 17-22.

Data from which these graphs are constructed are given in Table III.

Analysis and Interpretation

By reference to Tables I and II it is found that the intelligence of hookworm troops is lower than for the non-hookworm troops; that they have fewer years of schooling; and that they are younger chronologically. Mere inspection of the tables show these differences to be unmistakable and to be based on such a large number of cases as not to warrant computation of a mathematical probable error of these differences.[2] Furthermore, all these differences are greater for white troops from "light" territory than for those from "heavy" territory and, in most cases, greater for the white troops than for the colored troops.

Moreover, when, according to Table III and graphs, plates 17-22, hookworm and non-hookworm troops are compared by average score of successive 10% steps from the highest to the lowest, it is clear that the difference in intelligence rating between hookworm and non-hookworm troops of the lowest level of intelligence is comparatively slight. From this it is safe to infer that the lower the intellectual scale, the less the relative inferiority of the hookworm troops.

So much for the data. What do they mean? Before offering an interpretation, let there be a critical survey of earlier

[2] It should be noted that the sum of the Alpha cases and of the Beta cases of hookworm and non-hookworm groups, respectively, do not quite equal the total number for each group in the "Common Scale" column, since the difference was made up by the individually examined cases. Likewise the total numbers for the age and schooling columns do not, as they should, equal the totals of the Common Scale column, since some troops failed to note their age, some their schooling, and some, both.

studies of similar problems. The first study designed to measure the influence of hookworm disease on intelligence was made on school children by E. K. Strong under the auspices of the Rockefeller Foundation, in 1916.[3]

From his study, Strong concludes:

1. "Hookworm disease interferes very radically with mental development."

2. "Treatment alleviates this condition to some extent, but it does not, immediately at least, permit the child to gain as he would if he had not had the disease."

3. "The longer the child has the hookworm disease, the less will be the improvement mentally when the child is treated."

4. The last statement Strong considers as "probably the most important deduction from this whole study."

Such are Strong's conclusions, which corroborate the average man's casual observation of the apparent effect of hookworm disease and, in support of which, all who are interested in stamping out the disease are eagerly waiting for conclusive scientific data. *But neither Strong nor anyone else has yet produced such data.*

Strong compared the gains made in several of the then most highly standardized single group intelligence tests after a period of three and a half months by the following group of school children:

18 children without hookworm.
9 untreated hookworm children.
27 completely cured hookworm children.
17 incompletely cured hookworm children.

All these children were given the Binet-Simon Test, in addition to seven other mental tests, calculation test, logical memory, opposite test, memory span, handwriting, form-board test, all of which, together with the Binet test were repeated after an interval of three and a half months. The difference between chronological age and Binet age for the respective groups was found to be: non-hookworm children, —1.0 year; completely cured hookworm children, —1.6 years; incompletely cured hookworm children, —2.2 years; and untreated hookworm children, —1.2 years. According to the chronological age distribution for the various groups, all the non-treated hookworm children fall between the ages 9.9-10.9 years, while all the other groups are rather evenly divided between the age intervals 9.9-10.9 years and 11-12 years.

[3] Effect of Hookworm Disease on the Mental and Physical Development of Children. N. Y. The Rockefeller Foundation, 1916.

Now it has been pointed out that for ages above 10.5 or 10 years, mental age cannot be accurately determined by the old Binet test, which fact Strong himself records in a footnote of his study (page 74). Of this shortcoming of the old unrevised Binet test which was used by Strong, Terman has to say the following: "The proportion of feeble-mindedness among adult subjects was greatly overestimated, because subjects who were really of the 12 or 13 years mental level could only earn a mental age of about 11 years."[4] He finds furthermore that young subjects get too high a mental age: "In young subjects the higher grades of mental deficiency were overlooked, because the scale caused such subjects to test only a little below normal."

There is a very high probability then that Strong's mental ages are not the true mental ages and that the non-treated hookworm group, a comparatively young group, had a mental age deficiency of considerably over 1.2 years; and that since all the other groups fall pretty heavily into the 11 to 12 age group, their mental age deficiency found by Strong is too great. Indeed, on the basis of the age distribution of the groups it is highly probable that for increasing order of mental age deficiency the groups stand: non-hookworm children, completely cured hookworm children, incompletely cured hookworm children and untreated hookworm children.

Strong's data on the social status of the groups help corroborate this probability, for of the non-hookworm children 94% came from the best grade of homes, 0% from the poorest. Of the completely cured hookworm children 41% came from the best grade of homes, 15% from the poorest. Of the incompletely cured hookworm children 12% came from the best grade of homes, 29% from the poorest. Of the untreated hookworm children 33% came from the best grade of homes, 56% from the poorest. This is considered a corroboration of the assumption that better social environment on the whole presupposes a higher level of intelligence in that environment. Considerable data[5] are available in support of the latter assumption.

It so happened that on the whole the gains in the second trial of the several mental tests (other than Binet) classified the groups in the order, non-hookworm children, completely cured hookworm children, incompletely cured hookworm children and untreated hookworm children, which is the same

[4] The Measurement of Intelligence, Lewis M. Terman, p. 3.

[5] Lewis M. Terman, The Measurement of Intelligence, pp. 72-73. Robert M. Yerkes, James W. Bridges, Robert S. Hardwick, A Point Scale for Measuring Mental Ability.

order as the very highly probable mental age order of the groups to start with, as was shown above. *If the latter be true, then the order of gain is but to have been expected, hookworm or no hookworm.* It is now generally accepted as a fact that the more intelligent learner learns the more rapidly. Strong[6] himself has furnished data elsewhere which he apparently had forgot when interpreting his data on hookworm. He concludes from an experiment on school children:

"The slope of learning curves of school children based on simple arithmetical combinations apparently correlates to a very considerable extent with the general intelligence of the children." A few years previously Colvin, practicing five normal subjects with five subnormal at canceling A's, found that "in every case the normal child made greater improvement with less fluctuation than did the subnormal child."[7]

Likewise the writer found from a card sorting practice on 27 normal school students for 50 minutes a day, with the practice repeated after 10 days, 11 days and 3½ months, respectively, a positive correlation of +.48 between maximum gain and intelligence, when there was no correlation between initial performances and intelligence. This indicated pretty clearly that the +.48 correlation showed a very real positive relationship between intelligence and learning ability. It should be noted that "intelligence" was determined by having each student rank all the other students of the class on the basis of her estimate of each student's intelligence, from which a combined ranking was computed.[8]

Assuming, then, that the four groups studied by Strong had at the beginning of the study mental capacity in the order,—non-hookworm children, completely cured hookworm children; incompletely cured hookworm children, and untreated hookworm children; which his difference between chronological and mental ages (p. 21) indicates when these data are interpreted in the light of Terman's Revision of the Binet tests, that the gain, therefore, for these groups after 3½ months

[6] Learning Curve as a Diagnostic Measure of Intelligence,—Psychological Bulletin, 1917, Vol. 14 pp. 153-154.

[7] S. S. Colvin, Notes on Certain Aspects of Learning—Psychological Bulletin, Feb. 15, 1915, Vol 12.

[8] Garry C. Myers, Some Variabilities and Correlation in Learning. Amer. Jr. Psychol. July, 1918, Vol. 29 pp. 316-326.

Since completing this study the writer has demonstrated in a practical way that learning progress is in proportion to intelligence ratings, in a school of 1,800 illiterates whom he classified on the basis of intelligence ratings. See Principles, Plans and Purposes of the Recruit Educational Center, Camp Upton, N. Y., War Department, Washington, D. C.

should show exactly that order is just what should be expected, regardless of hookworm. *Apparently, then all Strong's study has shown is that brighter children learn faster than duller children.*

It must be said of Strong's work that his method of attempting to measure the effect of hookworm on mental development in terms of relative learning gains by hookworm and non-hookworm children is highly commendable. His method, if refined by comparing groups of equal mental and social status, on the basis of their learning rate as measured by learning curves developed with considerable practice on specific learning tasks and on large number of children, should help measure with a good deal of exactitude the influence of hookworm disease on intelligence.

Strong also studied 11 children—not included in the part reviewed above; who on the average were 13.5 years of age, comparing this group with the 17 incompletely cured hookworm children averaging 11.1 years chronologically, both groups coming " from homes of approximately the same economic conditions." The average mental ages for the respective groups, by Binet-Simon tests, were found to be 9.0 years, and 8.5 respectively, from which are derived intelligence quotients of .67 and .77. Of course, here again the real difference is not quite so great if the error of Binet for the older children is taken into account. Nevertheless, it is obvious that the older group of 11 children, as pointed out by Strong, is appreciably lower intellectually, which fact would presuppose a lower rate of gain by them, which gain was 1.5% as against 5.9% for the younger group. " When the two groups are compared with normal children, we see that the younger children have gained but 34% of what the healthy children accomplished, while the older children have gained but 9%." It should be recalled that this " normal " group had an average chronological age of 11.1 years and mental age of 10.1 years, giving an intelligence quotient of .91. Certainly, therefore, Strong is not justified because the older hookworm children with lower intelligence gain less than the younger hookworm children of higher intelligence, in concluding: *" The longer the child has the hookworm disease the less will be the improvement mentally when the child is treated."* And not justified in spite of the fact that he notes, " Our careful study made of these children (*the 13.5 year old children*) did not reveal any other cause for the retardation than hookworm disease." *Here again he has merely shown by his data that the brighter children learn faster than the duller children, which is to be expected.* Furthermore, it is not clear on what

ground Strong assumes that the 13.5 year old children with hookworm have had the disease longer than the 11.1 year old children.

In 1917 Truman Lee Kelly[9] reported a study in which his results disagree with those of Strong's to the effect that children cured of hookworm improve more rapidly in mental traits after cure than do the normal children.

He too had a small number of cases in the groups compared:

47 children free from malaria and hookworm.
9 children cured of hookworm.
11 children cured of malaria.
11 children cured of malaria and hookworm.

The tests were Starch, Arithmetic, Courtis Arithmetic, Trabue completion and Thorndike Reading tests, which were repeated after a six months' interval. Kelly gives no indication as to the mental status of the group compared at the time of the first test. Furthermore, since he depended upon the children's report as to whether or not they had malaria one is not sure this factor is wholly eliminated from the "free-from-malaria and hookworm" group.

If number of cases were the solution of this problem, the solution should have been near at hand upon the report of Waite's Study,[10] wherein he tested 116 non-infected children, 65 lightly infected children and 159 heavily infected children, with Goddard's Revision of the Binet-Simon Tests, and the Porteus Mazes. Waite classified his group in this way:

"1. The heavily infected cases presenting hookworm ova in plain smear examinations of stools;

"2. The lightly infected cases, presenting hookworm ova only in smears of centrifuged stools; and

"3. The non-infected cases, who showed no ova in four successive stool examinations, two of plain smears, and two of centrifuged smears."

Expressed in mental age the retardations for the respective groups for Binet and Porteus tests were as follows:

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[9] Effect of Malaria and Hookworm upon Physical and Mental Development of School Children. Elementary School Journal, Vol. 18, 1917, pp. 43-55.

[10] Dr. G. H. Waite, A Study of the Effects of Hookworm Infection upon the Mental Development of North Queensland School Children. The Australian Medical Journal Jan. 1919. The original manuscript dated 1918 was loaned the writer through Major John L. Riley, by the Library of the Rockefeller Foundation.

	Non-Infected	Lightly Infected	Heavily Infected
Retarded by Binet...	3.9 mo.	9.3 mo.	23.4 mo.
Retarded by Porteus	2.7 mo.	4.7 mo.	16.00 mo.

Unfortunately Waite computed the average retardation rather than the median, thereby giving undue weight to the extremely low cases. Nevertheless, these data show conclusively that the hookworm children studied are on the average more retarded mentally than the non-hookworm children, and the heavily infected group is more retarded than the lightly infected group. But they do not conclusively support the inferences derived therefrom by Waite, wherein he concludes:

1. "The results bring to light clearly two features, namely, that hookworm infection produces in growing children severely arrested mental development, and considerable mental sluggishness."

2. "The duration of hookworm infection is important, because the longer the infection persist the greater is the mental retardation."

3. "The degree of hookworm infection, and therefore the amount of anemia, definitely influences the amount of retardation of mental development."

4. "The most backward hookworm children invariably give the history of an early infection."

Considering Waite's first point, there arises the ever-present problem in interpretation of such data which he seems wholly to ignore, namely, how is anyone to know from any data which merely shows the hookworm group inferior in mental rating whether the inferiority is due to hookworm or whether because of their inferiority such children were of poor sanitary habits, thereby more exposed to the infection? In other words, to what degree does hookworm select the lower level of intelligence? Certainly Waite is not justified by the data he furnishes in making his first conclusion. On the basis of his data one could infer with just as much logic that "severely arrested mental development, and considerable mental sluggishness" tended to make the children easy victims to hookworm.

The validity of Waite's succeeding inferences hangs upon that of his first one.

In the study of Major Kofoid and Pittenger (see this paper, p. 211), their comparative data expressed in 10% steps from the highest to the lowest for hookworm and for non-hookworm

cases, respectively, indicate an even more pronounced tendency at convergence toward the lower extreme than does this study. Here are their data for Alpha:

			501 Hookworm Cases Aver. Score	4,792 Non-Hookworm Cases Aver. Score
1st	(Highest)	10%	181.0	219.0
2d	"	"	146.6	178.5
3d	"	"	118.6	150.6
4th	"	"	99.0	127.7
5th	"	"	80.4	107.4
6th	"	"	63.5	89.6
7th	"	"	48.7	70.7
8th	"	"	36.1	51.3
9th	"	"	24.6	31.8
10th	(Lowest)	10%	1.0	0.0

Median score.

Although their data were given in weighted scores which are about twice the unweighted scores in the present study, thereby rendering the two sets of data not wholly comparable, yet the general tendency is the same as that shown by our data. Of course their relative inferiority of the hookworm group is very much greater than that for our study, they also found a greater increase of difference from the lowest mental level to the highest. This is to be expected since their negative group was selected at random including troops undoubtedly from the larger urban populations and other non-infected or lightly infected areas, whereas each of our hookworm cases was paired with a non-hookworm case from the same local territory. They also found in accord with our data, that the relative inferiority of the hookworm troops was much greater for whites than for colored and greater also for Alpha troops than for Beta troops.

Interpreting these data Kofoid and Tucker say: "In literate blacks the difference is less, as might be expected, because of a relative racial immunity." They conclude:

"The interpretation of the data is that men infected with hookworm belong to all classes of mental rating, but not wholly proportionately in all groups to those without the infection, the men with the low scores showing a greater relative deficiency as the score falls. It also appears that the infected men are pushed *en masse* below the normal by infection by hookworm, or by other factors correlated therewith in a vicious

circle, but that the men with lower scores have a greater momentum and move relatively farther from the norm than do infected men with higher scores. This suggests the conclusion that men with hookworm include a greater proportion of subnormal types than men without and that subnormal men tend to acquire the disease more rapidly than men of higher categories. It is also possible that the intensity of individual infections may be heavier in the groups of lower intelligence, due to the relation of intelligence to sanitation, which in turn modifies the chances of infection and thus the ultimate intensity thereof."

As for the negroes, they logically fit into the lower order, consequently showing, as do the lower whites, a comparatively small inferiority for the hookworm group. Then the question may arise why is not the convergence consistent from the highest to the lowest extremes of intelligence instead of a rather sudden convergence toward the lower extreme? The answer may be that with the exception of the lowest 30 or 40% of the intelligence scale of a community, there is hardly to be expected a great improvement in sanitary habits near the more intellectual extreme. Certainly the degree of rise in standards is hardly proportional all the way upward. On the other hand, just why should the very upper extreme of the hookworm and non-hookworm groups be actually closer than the mean where there is a slight bulging in the space between the curves? Undoubtedly this is due to a failure of Alpha to differentiate as widely in intelligence scores for the upper extremes of intelligence. In the numerous studies of Alpha by the Division of Psychology it was invariably found that, on the basis of a man's military value, Alpha did not clearly discriminate between the upper and lower A grade man, nor even always between the A and B man.[11] Furthermore when given to college men, the discrimination in terms of intelligence rating is certainly not very pronounced.[12]

On the other hand, the convergence at the lower extreme may mean that hookworm disease in some peculiar way does not affect persons of very low mentality or even those of very high mentality or that the effect is so small as to be registered but slightly or not at all by an intelligence test. In this event the difference between the hookworm and non-hookworm groups would undoubtedly be due to hookworm infection.

If two groups, say from northern states where hookworm

[11] Psychological Examining in the United States Army, Part III. P. published by the National Academy of Sciences, Vol. XV.

[12] School and Society, Vol. X, No. 250, pp. 437-440.

is practically absent, whose median mental status were known to be quite disparate, were compared on the basis of 10% steps, comparison with such data would help clear up the difficulty in interpreting the lack of complete parallelism between the 10% steps of the hookworm and non-hookworm groups of this study.

In reading the data of Table I care should be exercised in interpreting per cents of difference in respect to all mental ratings since a year's difference between mental ages 7 and 8 years cannot mean the same as a year's difference between 11 and 12 years, nor in terms of per cent, since even in spite of intelligence scales there is no certainty that the increments in terms of mental age or even in terms of Alpha or Beta scores are constant. Let such per cents merely be read as ratios to the higher values compared and no more.

Relation of Schooling to Hookworm

When the amount of schooling reported is considered the data are no more conclusive in what they mean, for very high correlations were found between the army group tests and amount of schooling.[13]

Just what the high correlation between intelligence rating and schooling means is not certain, i. e., one does not know how much schooling offsets ability to score in the army tests nor to what degree the amount of native ability determined how long school had been attended. In this study exactly the same problem arises: Did hookworm disease decrease the amount of school attendance or was the kind of children whose school attendance was limited, of those children who most readily fell heir to the disease? Maybe such children were those less likely to have shoes and not having so much schooling and not coming perhaps from so good a social environment would not have developed so good sanitary habits.

Relation of Age to Hookworm

Since all the troops from among whom the cases selected were of practically the same age distribution, it is quite significant that the hookworm troops are from .7 to .9 of a year younger than the non-hookworm troops.

According to the report of the Porto Rico Commission,[14] there was found the following age distinction:

[13] Psychological Examining in the Army, Part III. National Academy of Sciences, Vol. XV.

[14] Ashford and Jgaravidez, Uncinariasis in Porto Rico, Sen. Dec. 808, Washington, D. C., 1911.

Age	*Cases*
Under 10 years	15,622
10 to 20 years	50,924
21 to 30 years	36,589
31 to 40 years	18,254
41 to 50 years	8,796
51 to 60 years	3,841
Over 60 years	1,413

Although the cases examined were not exactly a random sampling, these figures doubtless represent the approximate age distribution, and are slightly suggestive of a corroboration of our findings.

A study reported by Major Siler and Major Cole in 1917 is more to the point.[15]

Of the First Mississippi Infantry 32% were infected, and the First Alabama Cavalry, 54%. The age distribution for the highest 10 years were as follows:

Years	*First Mississippi* %	*First Alabama* %
16-17	1	2
18-19	21	42
20-21	32	24
22-23	20	12
23-24	11	7

Obviously the First Alabama Infantry, a greater per cent of whose troops have hookworm, are younger than those of the First Mississippi. In the light of these data the writers inferred (p. 95):

"In our opinion there is but little or no doubt that age accounts to some extent for the greater prevalence of both hookworm disease and measles in the First Alabama Cavalry."

From this data and from the present study (see plate 25-28) it seems that the younger troops are more susceptible to hookworm disease than the older troops. Certainly more data is desirable as to the exact distribution of hookworm cases on the basis of total population at various ages and in various racial levels. However, it is also probable, since hookworm infection is limited in its length of life within a given individual, that many of the older men, who, in the hookworm

[15] Major J. F. Siler, M. C. and Major C. L. Cole, M. C., The Prevalence of Hookworm Disease in the Fourth Texas Infantry, First Mississippi Infantry, and First Alabama Cavalry Regiment. The Military Surgeon, 1917, Vol. 41, pp. 77-99.

survey fell into the non-hookworm group, had once been hookworm cases but had become free from hookworm at some time previous to the hookworm examination.

Conclusion

The average person of a given community, who is infected with hookworm, is inferior mentally to the average person, of the same community, who is not infected with hookworm. In support of this statement conclusive data have been presented.

But there are yet no data available to show conclusively whether this mental inferiority is due to hookworm disease or whether hookworm disease is due to mental inferiority.

A fact not calling for evidence here is that hookworm disease is a social and economic burden upon tropical and subtropical countries. Now if it does not in and of itself lower the mentality of its victim, there is ample evidence that it will, as will any other disease, diminish his educational opportunities, and thereby his efficiency as a social unit.

Since because of the very nature of the transmission of hookworm disease, wholly dependent upon remedial sanitary habits and conditions, doubtless it is true that just because of lower intelligence or lower mental training the victim more readily falls heir to the disease; hence the obvious remedy is more education to the educable, a far stricter governmental guardianship over the non-educable and over those educable to but a slight degree, and an aggressive general governmental control over the social habits and sanitary conditions of the community. In matters of education, mere ability to master the three R's should not be the goal alone, but through this median specific instruction in matters of simple rules of health and sanitation is of imperative necessity.

This emphasis upon specific hygiene instructions is obviously none the less imperative if it is discovered that the hookworm infection is primarily the cause of the relatively lower mental status of its victims.

So, then, whether hookworm disease is the cause of mental inferiority or the result, or both, the fact that those infected with the disease are, as a rule, distinctly inferior to those free from the disease, as shown conclusively by this study, is an inexorable challenge to the federal, state and local leaders in matters of health education and general economic and social betterment, to use every possible means to rid the country of this pest.

Suggestions for Further Research

The question remaining to be answered is, Does hookworm disease directly depreciate the mental status of its victims?

It has been seen that Strong's method of comparing gains in learning by the cured-of-hookworm children with hookworm children, while on the right track apparently, was fallacious in that it ignored the fact that ability to learn correlates highly with general intelligence; and, that as subsequent studies and as his own data indicate, almost any randomly selected hookworm group will be found to be of lower mental status than a non-hookworm group similarly selected.

It is necessary, therefore, in order to make a fair comparison, to be sure that the groups compared are at the time of the first learning test of practically the same mental ability with practically equal distribution of abilities in the groups compared.

Furthermore, the social status of the compared groups should be equal. A study of infected and non-infected children of the same family (especially of twins) would meet both conditions fairly well. That the social status be equalized in such cases would be obvious and that twins show far closer mental resemblance than siblings and siblings far closer resemblance than randomly selected children, has been well established by Galton,[16] Thorndike,[17] Rusk,[18] Cobb,[19] Starch,[20] and others.

In the absence of either class of subjects to be studied, the group intelligence tests available would enable the selection of groups of practically the same mental abilities.

If, then, of those two groups, the hookworm group learned appreciably more slowly than the non-hookworm group or cured-of-hookworm group, the obvious inference would be pretty safe.

The learning task should extend over a period of several weeks or months including numerous practices, thereby offering opportunities to measure mental endurance and attitude toward a task whose novelty has worn off and wherein the stimulation of a stranger as examiner has ceased to function as a stimulation.

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[16] Sir Francis Galton, History of Twins, p. 170 f of the reprint in Everyman's Library.

[17] E. L. Thorndike, Measurement of Twins, Archives of Philosophy, Psychology and Scientific Methods No. 1, 1905.

[18] Elizabeth Rusk, Mental Resemblance among Siblings. Teachers College, 1908, Masters Thesis, (unpublished)

[19] Margaret V. Cobb, A Preliminary Study of the Inheritance of Arithmetical Abilities. Journal of Educational Psychology 1917, Vol. 8,—pp. 1-20.

[20] Daniel Starch, The Similarity of Brothers and Sisters in Mental Traits. Psychological Review 1917, Vol. 24, pp. 235-238.

Assuming that the infection does not depreciate the mental organism structurally, even then in terms of attitude there would remain the question of functional depreciation. It is desirable then to devise a test to measure the attitude of the learner toward his task. Admittedly this is difficult of measure, yet, the difference in the learning gains by two groups who on setting out upon the task are of equal intelligence, should be a fairly good measure.

Suppose, for example, two such groups are tested at a given time and after, say six months, are retested, and show the same gains. Even then their learning abilities under normal procedure may not be proved equal; for if on the other hand the test had been repeated 75 times on as many days or if the children had been at regular school work with their teacher, the one group may have lagged in interest far more than the other.

Certainly the factor of attitude and of stimulation under peculiar conditions have not been carefully taken into account in some of the widely read experiments whose data seem to show, for example, that rebreathed but circulated air is quite as good for the child's mental function as freshened air or that there is no such thing as mental fatigue or that certain drugs have little or no impairing effect on mental functioning, when they offer no such conclusive proof at all.

Professor James, somewhere, has pointed out that few persons work up to the limit of their capacity; J. J. B. Morgan,[21] that subjects lifting weight not visible, by means of pulleys, tend to lift with the same speed, within certain limits, regardless of the intensities of the weights. It has been shown[22] that learners continue to improve under intensive practice to a very remarkable degree under stimulation of rivalry. In another study[23] the writer has shown that by learning against time, the ordinary learning record can be improved to surprising degree.

A learning test, then, over a long period of time, with many practices, on members of a large hookworm group compared with similar data on a large non-hookworm group, both of practically the same mental and social status at the beginning of the test, with the diagnosis and cure of the disease under control, should yield a definite answer to the question of the mental influence of hook worm disease.

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[21] J. J. B. Morgan, The Overcoming of Distraction and other Resistances. Archives of Psychology #35, Science Press.

[22] Garry C. Myers, Hazel Coburn, Helen Collins, School and Society 1918, Vol. 8 pp. 597-600.

[23] Garry C. Myers, Learning Against Time. Jr. Ed. Psychology, February 1915, pp. 115-116.

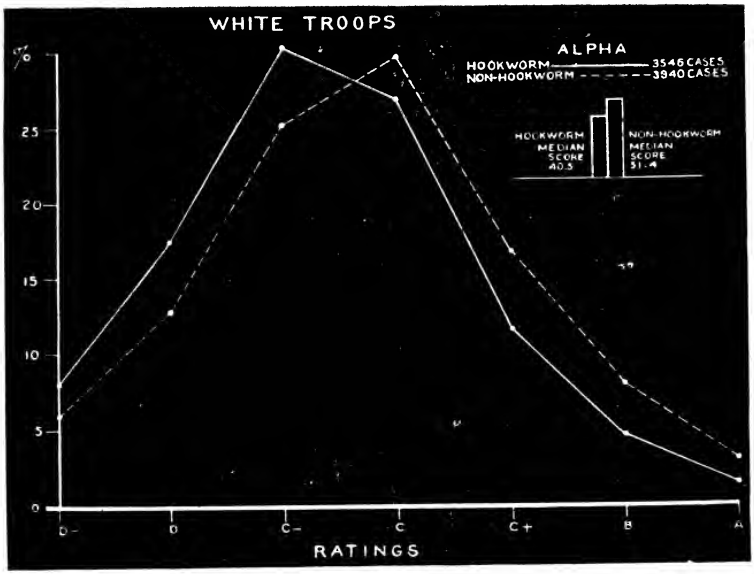
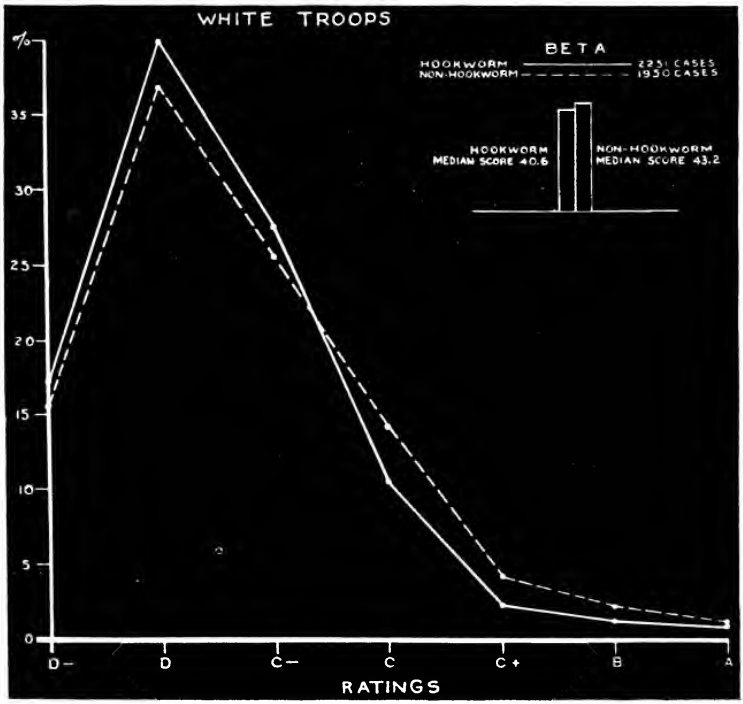


PLATE 1



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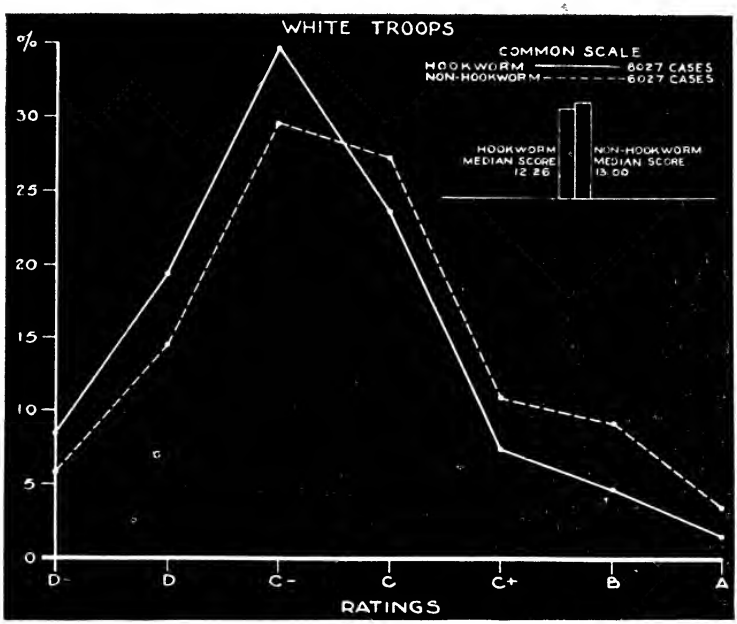

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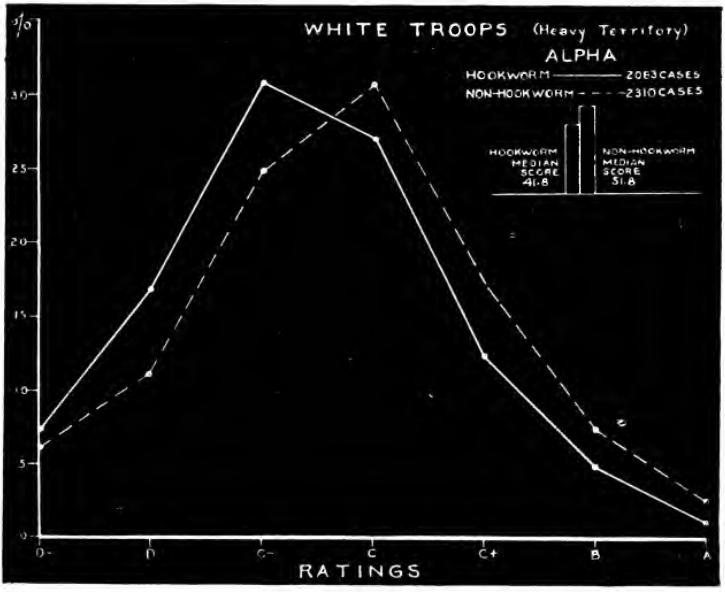

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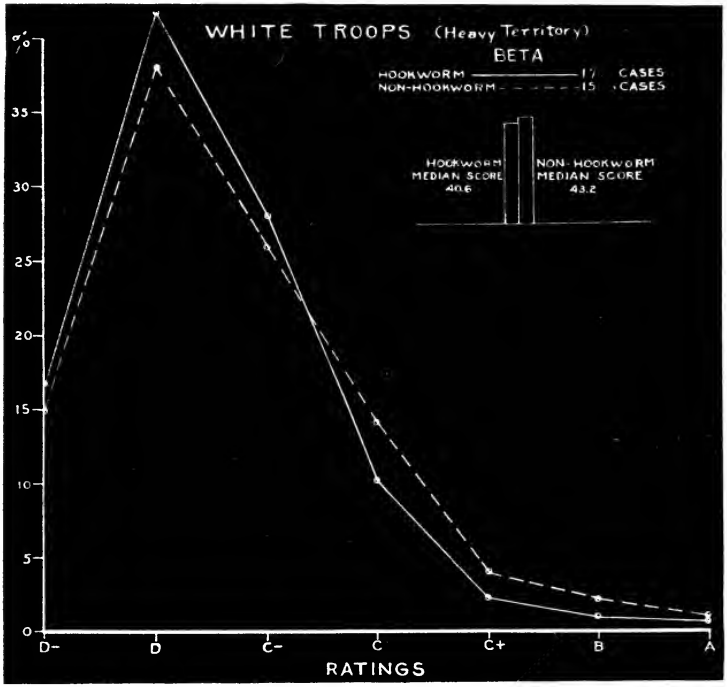

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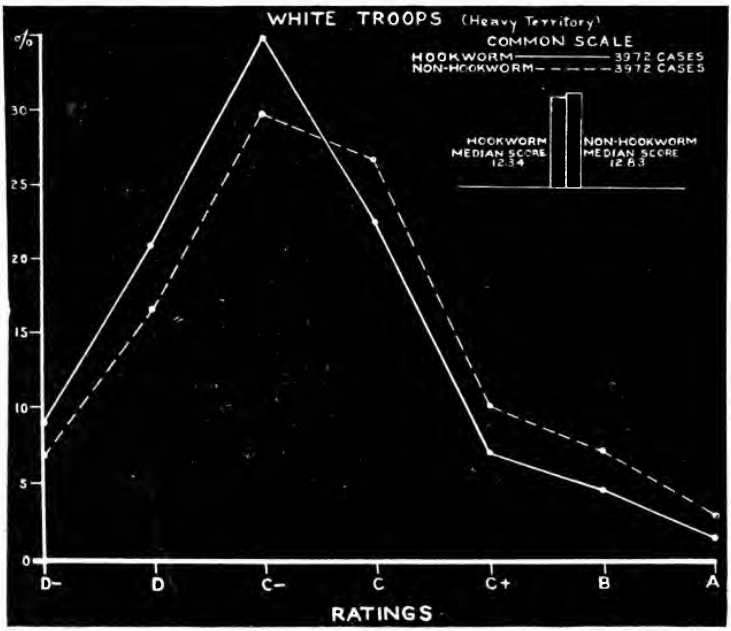

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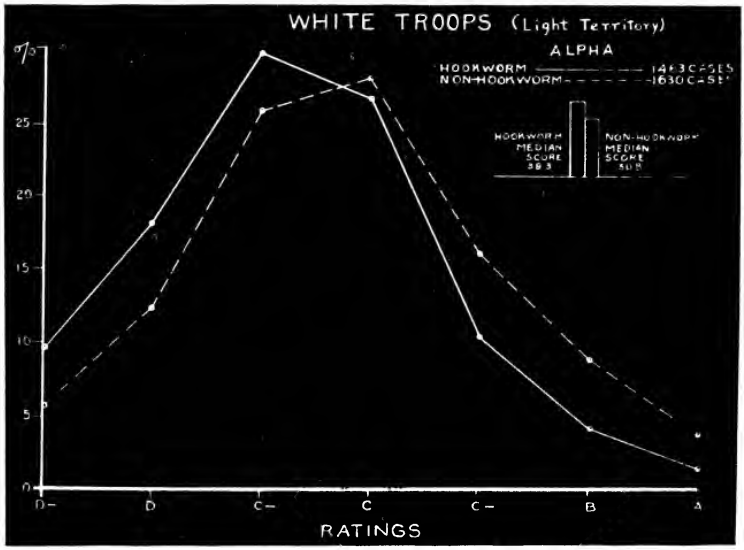

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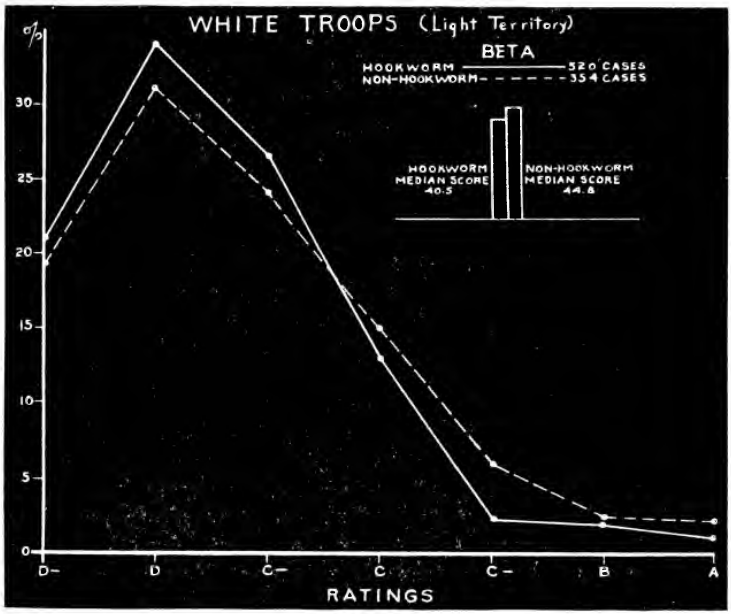

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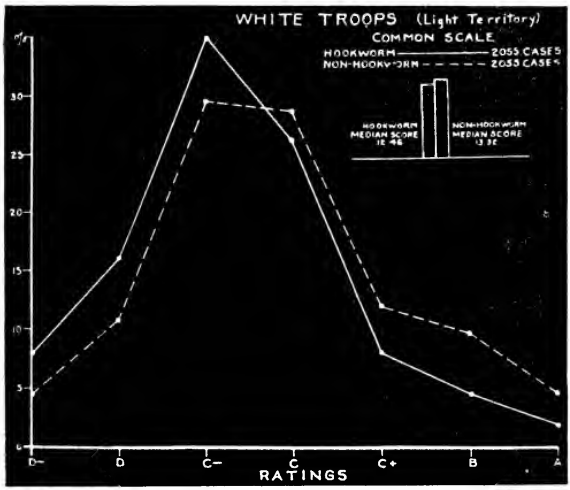

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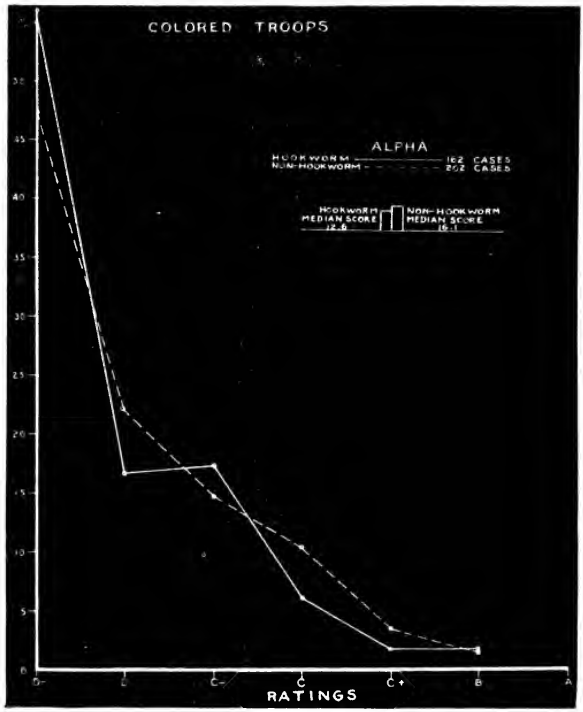

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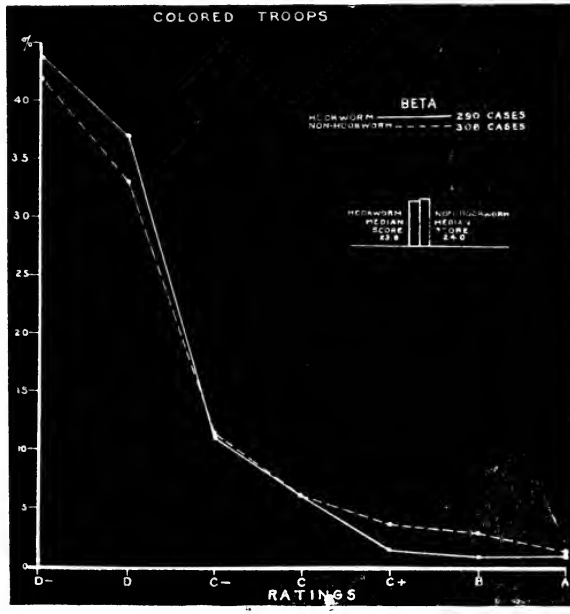

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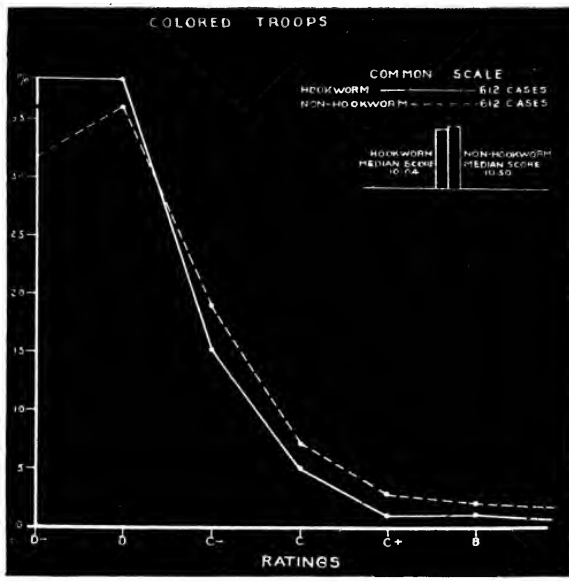

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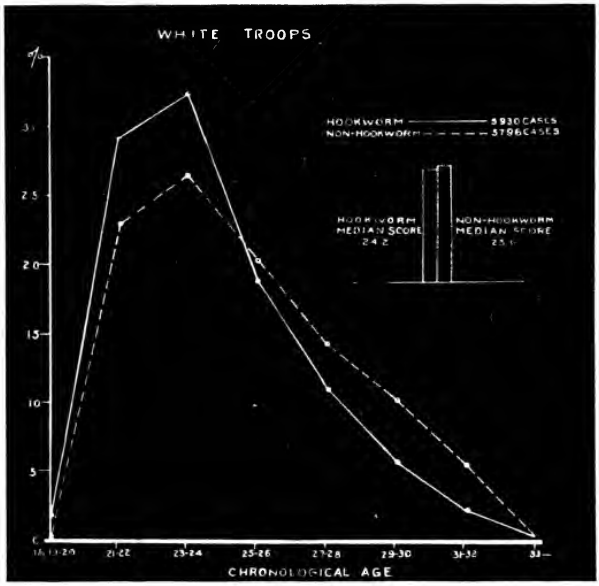

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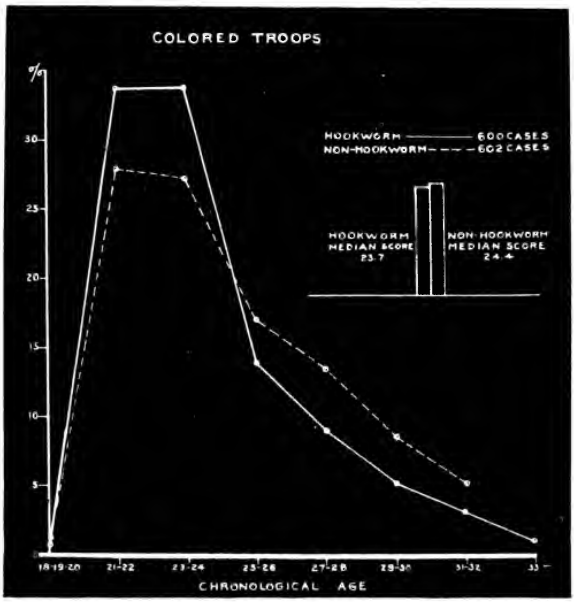

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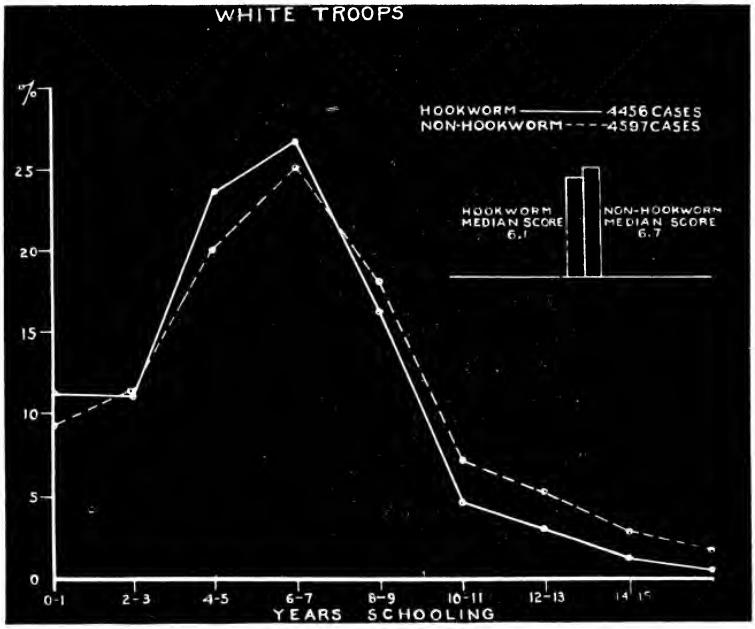

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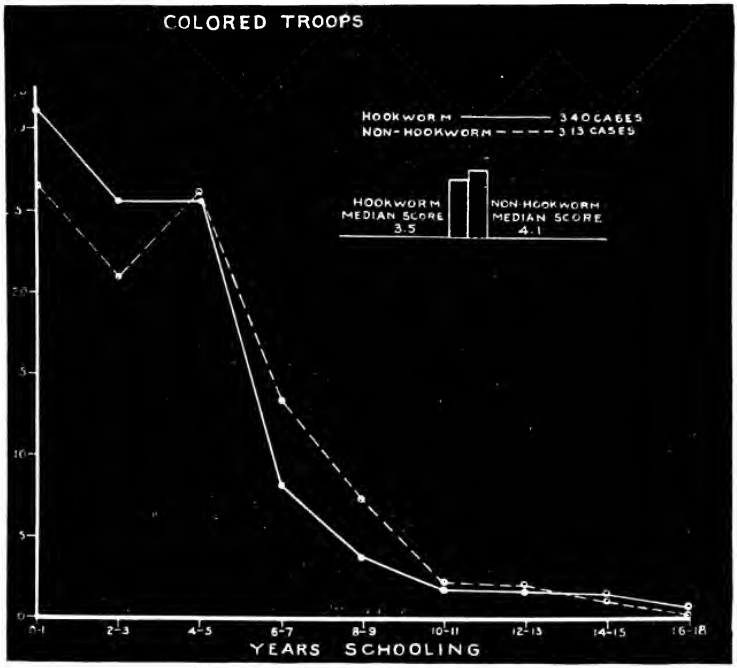

PLATE 16

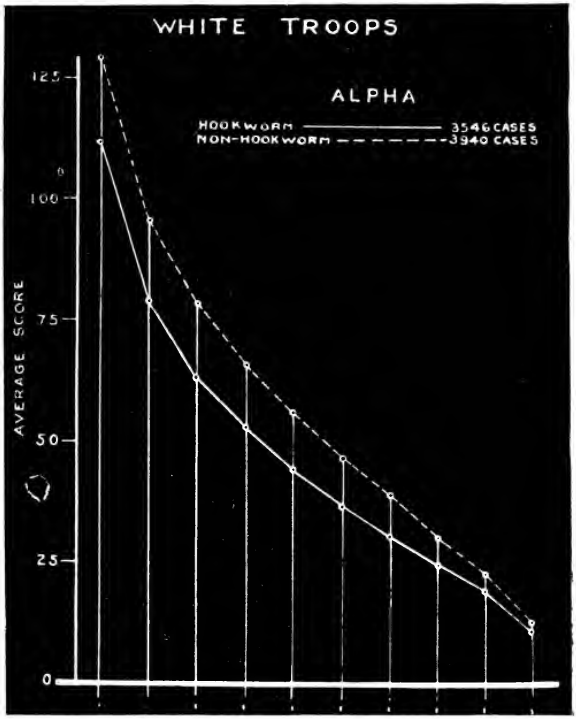

PLATE 17

SUCCESSIVE TEN PER CENT GROUPS

Highest 10%	2nd 10%	3rd 10%	4th 10%	5th 10%	6th 10%	7th 10%	8th 10%	9th 10%	Lowest 10%

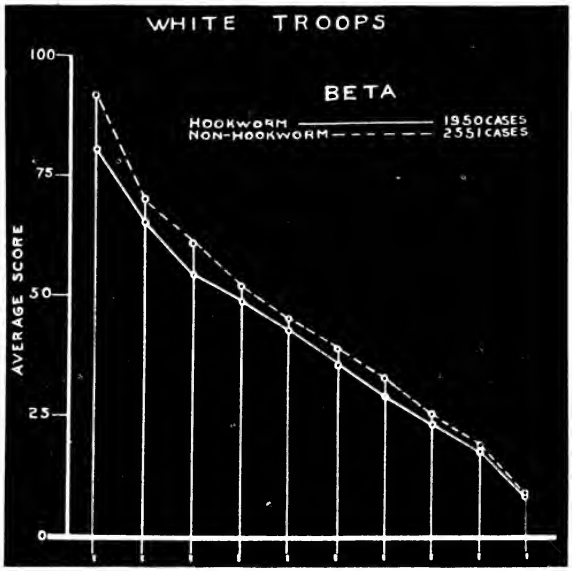

PLATE 18

SUCCESSIVE TEN PER CENT GROUPS

Highest 10%	2nd 10%	3rd 10%	4th 10%	5th 10%	6th 10%	7th 10%	8th 10%	9th 10%	Lowest 10%

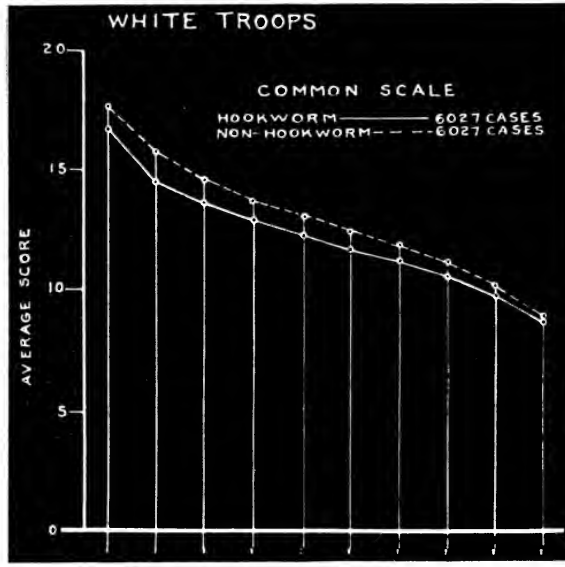

PLATE 19

SUCCESSIVE TEN PER CENT GROUPS

Highest 10%	2nd 10%	3rd 10%	4th 10%	5th 10%	6th 10%	7th 10%	8th 10%	9th 10%	Lowest 10%

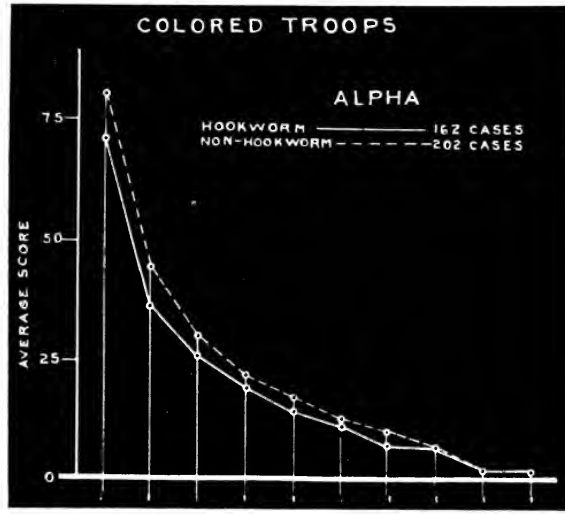

PLATE 20

SUCCESSIVE TEN PER CENT GROUPS

Highest 10%	2nd 10%	3rd 10%	4th 10%	5th 10%	6th 10%	7th 10%	8th 10%	9th 10%	Lowest 10%

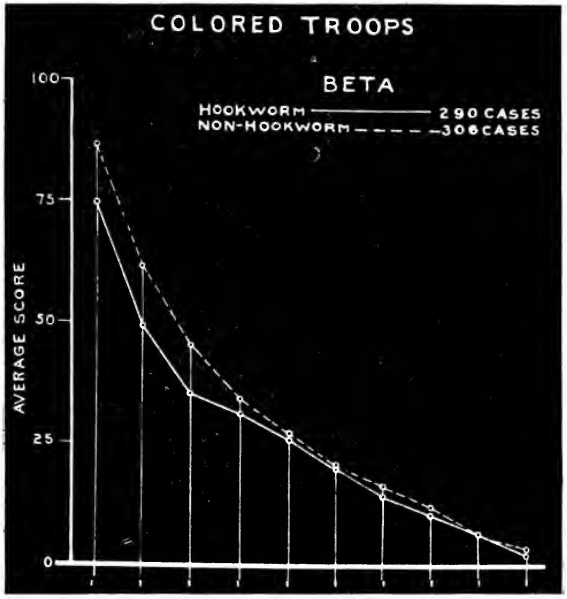

PLATE 21

SUCCESSIVE TEN PER CENT GROUPS

Highest 10% | 2nd 10% | 3rd 10% | 4th 10% | 5th 10% | 6th 10% | 7th 10% | 8th 10% | 9th 10% | Lowest 10%

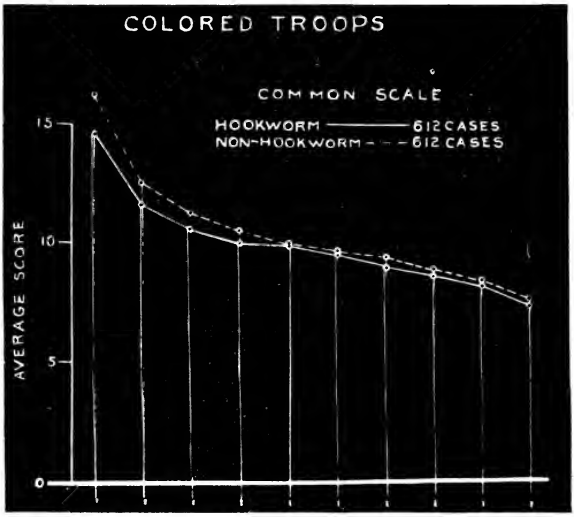

PLATE 22

SUCCESSIVE TEN PER CENT GROUPS

Highest 10% | 2nd 10% | 3rd 10% | 4th 10% | 5th 10% | 6th 10% | 7th 10% | 8th 10% | 9th 10% | Lowest 10%