A cardio-vascular rating of "present condition".

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With 1 Figures.

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For years physicians have used pulse-rate and systolic pressure as indicators of condition. One of the first attempts, however, to combine pulse-rate and blood pressure findings to form a scorable test was that of *Crampton* in his "Blood Ptosis", published in 1905. This was followed by *McCurdy*'s Condition Test in 1910, by *Meylan*'s test in 1913, by *Foster*'s test in 1914, by the *Barach* test in 1914, the *Schneider* test in 1920, the *Pulse-Ratio* test in 1925, together with a number of variations of such tests as that of the Michigan State tests of 1920 and the California test in 1923.

Of these tests, described elsewhere, the one which has by common consent been considered to be the most effective for the diagnosis of "present condition" is the *Schneider* test, in which the reclining and standing pulse-rates, the pulse-rate increase on standing, the pulse-rate immediately after a fixed amount of exercise, the return of pulse-rate after exercise to the standing normal, and the difference in systolic pressure, standing and lying, were taken as the variables. This test was based upon studies of aviation recruits during the war and had as its rating criterion medical examinations with the subjective rating of physicians. The statistical techniques used were limited and the scoring tables developed were arbitrary and were not subjected to proof of their validity.

The present study was begun in an attempt to seek a more valid method of devising such tests. Among the practical problems involved was, first, that one conducting such tests must use measurable variables which are practicable, such as those utilized by *Schneider*, and possibly diastolic pressures as well. The second problem was to determine the correlation of each of these variables with present condition, and to find a method of correlating them.

In the methods formerly used, there was a lack of objectivity. If one were to simply utilize the present tests, such as the *Schneider* test, and correlate to that, it would correspond somewhat to endeavoring to lift oneself by ones statistical bootstraps. If one were to depend entirely upon the subjective judgments of physicians, these also would be open to criticism.

It occurred to us to utilize the ordinary methods of multiple correlations, inter-correlating the different variables by the ordinary product-moment method but using the method termed bi-serial "r" as the means of correlating each variable with a criterion of present condition. The bi-serial "r" method utilizes two groups of individuals falling in separate categories along one axis but showing ordinary numerical variability in the other axis. For example, if we could secure two groups of individuals, one of which could reasonably be presumed to be in "good condition" and the other of which could be presumed to be in "poor condition" and if, furthermore, one could be reasonably certain of meeting the other conditions of normality of distribution, which are usually assumed, this method of correlation could then be combined with the others in the larger problem of multiple correlation. In this study we investigated the possibilities of this method of solving the problem. We make no pretense of offering the results of our study as the final solution, as the number of cases studied was relatively small and the group lacked homogeneity in the ages of its subjects.

Material used.

We had available as research material the records of the study of the physiological effects of golf made by Dr. *P. V. Karpovich* and printed in the American Physical Education Review, November, 1928. We selected for our first group eighteen individuals from various Westchester County golf links, all of whom were able to play at least eighteen holes of golf. Our second group was composed of twenty-one patients of the Burke Foundation of White Plains, New York. This institution is a convalescent home and these patients could reasonably be considered not to be in as good "present condition" as the golf players comprising the first group. All, however, were able to play some rather gentle golf on the course of the Foundation. Both groups were men. The age ranges were considerably too large for the best results in a scientific study, and the "well" group averaged eleven years older than the "ill" group. This would, however, simply have the effect in this case of somewhat lowering our correlations without invalidating the results of the study or the method used.

The thirty-nine subjects chosen will, it can be seen, satisfy the criterion of two groups which do not overlap very much in condition and who represent the two categories of good and poor condition. The criterion of normality, however, is not quite so easily substantiated. There were not available any ratings of condition and we were forced to fall back upon various devices. It was found that several variables, such as pulse-rate, systolic pressure, and the like did tend to fall in something approaching normal distributions, when these small numbers were taken into consideration. Hence, it was felt that we were justified experimentally in continuing the study and ascertaining what the comparative results would be.

Variables studied.

We had available the following possible variables which were numbered as follows:

0 — Condition
1 — Reclining pulse-rate
2 — Reclining systolic pressure
3 — Reclining diastolic pressure
4 — Standing pulse-rate
5 — Standing systolic pressure
6 — Standing diastolic pressure
7 — Reclining pulse pressure
8 — Standing pulse pressure
9 — Pulse-rate following exercise
10 — Pulse-rate sixty seconds after exercise
11 — Increase of pulse-rate upon standing
12 — Increase of pulse-rate upon exercising
13 — Time of return to normal after exercise
14 — Increase of systolic pressure upon standing
15 — Increase of diastolic pressure upon standing

Each of these variables was correlated with "present condition" using the method of bi-serial "r". The resulting correlations were as follows:

r 01 — .4170
r 02 — .1760
r 03 + .5067
r 04 — .4835
r 05 — .1492
r 06 + .6379
r 07 — .2795
r 08 — .3540
r 09 — .4719
r 0 (10) + .2012
r 0 (11) + .1502
r 0 (12) + .0575
r 0 (13) + .1553
r 0 (14) + .0176
r 0 (15) + .1904

The probable errors of these coefficients run from about .09 for the largest to .15 for the smallest coefficients. This would render some of the coefficients of exceedingly dubious value and in most cases this impression is confirmed by the partial coefficients computed.

An attempt was first made to evaluate certain of the variables to ascertain whether or not they were worth being retained. Owing to the large number of variables, it was not felt worthwhile doing the enormous amount of statistical computations necessitated by running out partial correlations on everything.

Pulse rates—lying and standing.

Lying and standing pulse-rates were each statistically significant. These were then tested to find whether one could take the place of the other. When standing pulse rate was held constant, reclining pulse rate gave us a correlation with condition of only —.0092, while with reclining pulse rate held constant, standing pulse-rate correlated —.2694 with condition. We therefore decided to eliminate reclining pulse-rate from further consideration. This decision was strengthened when it was found that reclining pulse-rate with pulse-rate after exercise held constant correlated only —.0800.

Variables 10, 11, 12, and 13, gave correlations only slightly greater than their probable error and were, therefore, not statistically significant. This was certainly true of variable 12, increase of pulse-rate after exercise. These impressions were confirmed when other items were partialed out. Hence, it was decided to eliminate these four also from consideration. The detailed evidence for this will be given at the end of this paper.

Systolic pressure.

The systolic pressure coefficients of correlation were all low, being very close to their probable errors. Since these coefficients had been used by *Crampton* and *Schneider* a more detailed study was made. With standing pulse-rate held constant, reclining systolic pressure correlates with condition —.0517. With standing systolic pressure held constant, the reclining systolic pressure correlates only —.0991 with condition.

Standing systolic pressure, with lying systolic pressure held constant, correlates .0277 with condition.

Standing systolic pressure, with standing and reclining pulse-rate held constant, correlates with condition —.0320, and with reclining pulse-rate and systolic pressure held constant, correlate —.0414 with condition. These low correlations suggested the elimination of systolic pressure entirely.

Diastolic pressure.

Reclining diastolic pressure with reclining systolic pressure held constant correlates .5803 with condition. Standing diastolic pressure with standing systolic pressure held constant correlates .6690 with condition. Standing diastolic pressure with standing pulse-rate held constant is also high, correlating .6557 with condition. It will be seen from the appended table that the diastolic pressures correlate highly with condition regardless of what is partialed out. With standing diastolic pressure held constant, reclining diastolic pressure has a correlation of only .1780 with condition, but with the opposite arrangement we get 4767. We, therefore, temporarily decided to retain standing diastolic pressure and to eliminate reclining diastolic pressure. Our decision was influenced in this case by the fact that we had also eliminated reclining pulse-rate and both of the systolic pressures. Increase in diastolic pressure upon standing gives too low a correlation to be significant.

Pulse pressure.

Standing pulse pressure with standing diastolic pressure held constant gives a correlation of only —.0692 with condition, and reclining pulse pressure also gives insignificant correlations when other significant items are held constant. For example, with reclining diastolic pressure held constant, pulse pressure correlates .0436 with condition; and with pulse-rate held constant, the correlation is —.1434 with condition. These two items are therefore eliminated.

This left us with standing pulse-rate, pulse-rate after exercise, and standing diastolic pressure as items of proven significance. These were then inter-correlated and the weighting devised. Several other combinations were tried. The multiple correlations resulting therefrom are as follows:

R 0.46 = .7505
R 0.469 = .7847
R 0.49 = .5085
R 0.49 (13) = .5442
R 0.49 (11) (13) = .5814
R 0.469 (13) = .8770
R 0.469 (11) (13) = .8862

The above combinations demonstrated that standing pulse-rate and standing diastolic pressure were the most important variables. The addition of pulse-rate after exercise did not increase this very significantly. To use the five variables of standing pulse-rate, diastolic pressure, pulse-rate after exercise, increase of pulse-rate on standing, and return of pulse-rate to normal, raises the correlation considerably. Owing to the small two-variable correlations, however, we believed that this was probably a spuriously high correlation due to chance variation and that we were not justified in retaining more than the variables of standing pulse-rate, diastolic pressure, and pulse-rate after exercise. When we retained only standing pulse-rate, standing diastolic pressure and pulse-rate after excercise, we were able to form two fairly satisfactory and relatively simple tests. We took the best combination of these variables and computed their correlation with "present condition" using bi-serial "r" which gave the following correlations; these can be compared with the multiple correlations given above:

$$R\,0.46 = .7387$$
$$R\,0.469 = .8032$$

It will be seen that these values are not far from the estimated values.

It will be of interest to compare these values with the results obtained from other tests. With our material, we could compute the correlations between "present condition" and the *Crampton* test, the *Foster* test, the difference between pulse-rate reclining and standing as proposed by *McCurdy*, and the *Schneider* test. These correlations were as follows:

Crampton	r =	.0101
Foster	r =	—.1928
McCurdy	r =	.1502
Schneider	r =	.4140

It will be seen that the *Crampton* test is of no more value than a random guess, so far as this group went. The *McCurdy* test ist about the same size as the probable error and is probably not at all significant. The *Foster* test gives higher scores to the convalescents than to the well. The *Schneider* test is considerably better than these others.

Another method of comparison is to use what has been called the Predictive Index. The Predictive Index is $1 - \sqrt{1 - r^2}$. This number can be considered about the same as percentage. It renders correlations much more readily comparable. The Predictive Index of variables 4, 6, 9, as correlated with condition is .4043. Of variables 4 and 6 alone .3260, and the *Schneider* index .0897. Hence, using the three variables, we get a predictive value which is approximately four and one-half times as reliable as the *Schneider* test, and using only two variables we get an index that is three and six-tenths times as reliable.

It must be emphasized that the smallness of the group studied makes this true only for this number of cases. The probable errors are sufficiently high to make generalization upon these unsafe. On the other hand, it is probable that either of these methods is more reliable than the *Schneider* test, in spite of the small number from which these standards are deduced. The contribution of this paper, however, is not in its formulae but in the validation of a method of study which should in the very near future give us as ideal a type of test of this nature as it is possible to obtain.

Formulae.

The formula for rating the variables is as follows:

I. The three variables—standing pulse-rate, standing diastolic pressure, and pulse-rate after exercise:

(4.46 D.P.) — (S.P.R.) — (3 P.R. after exercise).

The norms for this combination would seem roughly to be, if above zero, in satisfactory condition; if below zero, in unsatisfactory condition. In our results, only four out of eighteen of those supposedly in good condition are below zero. Our results run as high as 100. The median is 40. Only three of the group supposed to be in poor condition are at zero or above and they run as low as —260. The median is —54.

II. For the two variables, standing pulse-rate and standing diastolic pressure, the formula is:

$$(.89 \text{ D.P.}) - (\text{S.P.R.}) + 16.$$

The standard again is the zero line. In our study, there were but four below in the "good" condition group, and but five above in the "poor" group. In our study the results of the "good" group ran as high as 28, and of the "poor" group as low as —44.

If it is desired to use all of the variables showing any possible usefulness, the formula which could be adopted would be as follows:

$$(3 \text{ S.D.P.}) + (\tfrac{1}{3} \text{ increase of P.R. on standing}) - (\text{S.P.R.}) - (2.5 \text{ P.R. after exercise}) + 2 \text{ return to normal}).$$

In this case, "return to normal" is the pulse-rate from 45 to 60 seconds after exercise minus the standing pulse-rate before exercise expressed in beats per minute. Standards have not been computed for this as we do not feel it can be a reliable formula.

Summary.

Using a method of statistical research enabling one to compute correlations with "present condition," several simple formulae have been devised for scoring "present condition." Tested on a small group of thirty-nine individuals, these formulae are from three and one-half to four and six-tenths times as valid as the score obtained from the *Schneider* test.

The formulae given in this study cannot be considered as being reliable for ordinary use because of the small number of cases from which they were derived. However, the method presented is, we believe, a reliable one.

Correlations.

r 01	= —.4170	r 03.4	= .4576	r 4 (13) .9	= —.0286
r 01.2	= —.3843	r 03.6	= .1780	r 4 (13) . (11)	= .1208
r 01.4	= —.0092	r 03.14	= .4580	r 46.9 (11)	= —.3941
r 01.9	= —.0800			r 46.9 (13)	= —.1847
r 01.49	= .0726	r 04	= —.4835	r 46. (11) (13)	= —.2252
r 12.4	= .3202	r 04.1	= —.2694	r 49.6 (13)	= .7662
r 13.4	= —.0654	r 04.5	= —.4723	r 49. (11) (13)	= .7678
r 14.9	= .6287	r 04.6	= —.5133	r 4 (11) .9 (13)	= .2645

r 15.2 = .1763
r 16.4 = —.2549
r 18.4 = .5040
r 19.2 = .7860
r 19.4 = .4129
r 1 (12) .2 = .4696
r 1 (13) .2 = .0328
r 1 (13) .4 = —.0540
r 1 (13) .49 = —.1109

r 02 = —.1760
r 02.3 = —.3677
r 02.4 = —.0517
r 02.5 = —.0991
r 02.14 = —.0515
r 27.3 = .9630
r 2 (15) .5 = .2948

r 03 = .5067
r 03.2 = .5803

r 04.9 = —.2149
r 04. (11) = —.5024
r 04. (13) = —.5052
r 04.69 = —.1203
r 04.6 (13) = —.5176
r 04.9 (11) = —.2434
r 04.9 (13) = —.2146
r 04. (11) (13) = —.5476
r 04.69 (11) = .0480
r 04.69 (13) = —.0010
r 04.6 (11) (13) = —.5310
r 04.9 (11) (13) = —.2868
r 04.69 (11) (13) = —.1402
r 46.9 = —.1859
r 46. (11) = .2832
r 46. (13) = —.1719
r 49.6 = .7705
r 49. (11) = .7835
r 49. (13) = .7648
r 4 (11) . (13)=.1412

r 4 (13) .69 = .0181
r 4 (13) .9 (11) = .0323
r 46.9 (11) (13) = —.2788
r 49.6 (11) (13) = .7754
r 4 (11) .69 (13) = .3384
r 4 (13) .69 (11) = .0480

r 05 = —.1492
r 05.2 = .0277
r 05.6 = —.2986
r 05.12 = —.0414
r 05.14 = —.0320
r 58.6 = .9856

r 06 = .6379
r 06.3 = .4767
r 06.4 = .6557
r 06.5 = .6690
r 06.9 = .7060
r 06. (11) = .6252

r 06.(13) = .6262
r 06.14 = .6758
r 06.49 = .7773
r 06.9 (11) = .6978
r 06.9 (13) = .6863
r 06. (11) (13) = .6076
r 06.49 (13) = .6737
r 06.9 (11) (13) = .6702
r 06.49 (11) (13) = —.3383
r 69.4 = + .1223
r 69. (11) = —.0189
r 69. (13) = —.0695
r 6 (11) . (13) = .2925
r 6 (13) .9 = .2462
r 6 (13) . (11) = .2832
r 69. (11) (13) = —.0611
r 6 (11) .9 (13) = .2908
r 6 (13) .9 (11) = .2007

r 07 = —.2795
r 07.2 = —.2217
r 07.3 = —.0436
r 07.14 = —.1434

r 08. = —.3540
r 08.4 = —.2741
r 08.5 = .3494
r 08.6 = —.0692

r 08.14 = —.3121

r 09 = —.4719
r 09.1 = —.2551
r 09.4 = —.1802
r 09.6 = —.5855
r 09. (11) = .4682
r 09. (13) = —.5045
r 09.14 = —.1937
r 09.46 = —.3473
r 09.4 (13) = —.2124
r 09.6 (13) = —.5927
r 09. (11) (13) = —.5069
r 09.46 (13) = —.3568
r 09.4 (11) (13) = —.1614
r 09.6 (11) (13) = —.5927
r 09.46 (11) (13) = + .2111
r 9 (11) . (13) = —.0380
r 9 (13) .2 = .1333
r 9 (13) . (11) = .1288
r 9 (13) . 12 = .1740

r 0 (10) = .2012

r 0 (11) = .1502
r 0 (11) .4 = .2442
r 0 (11) . (13) = .1908
ro (11) . 9 (13) = .1989
r 0 (11) .49 (13) = .2715

r 0 (11) .69 (13) = —.0010
r 0 (11) .469(13) = .0435

r 0 (12) = .0575
r 0 (12) .4= —.1296
r 0 (12) .9 = .2452
r 0 (12) .14 = —.1419
r 0 (12) .149 = .0154

r 0 (13) = .1553
r 0 (13) .4 = .2253
r 0 (13) .9 = .2536
r 0 (13) . (11) = .1947
r 0 (13) .49 = .196
r 0 (13) .69 = .1163
r 0 (13) .9 (11) = .2910
r 0 (13) .469 = .1391
r 0 (13) .49 (11) = .3377
r 0 (13) .69 (11) = .2152
r 0 (13) .469 (11) = .6416
r 0 (14) = .0176
r 0 (14) . (11) = .0138
r 0 (14) . 14 = — .0440
r 0 (14) .25 = .0221
r 0 (15) = .1904
r 0 (15) .5 = .1571
r 0 (15) .25 = .1345

(4.46 S.D.P.)—(S.P.R.)—(3 P.R. after exercise.)

	B	A
100		1
80		1
60		4
40		3
20	2	1
0	1	4
— 20	2	2
— 40	2	
— 60	5	1
— 80	2	1
— 100		
— 120	1	
— 140	1	
— 160		
— 180	3	
— 200		
— 220	1	
— 240		
— 260	1	
— 280		
	21	18

r = .8032

(.89 S.D.P.)—(S.P.R.) + 16

	B	A
12		1
8		4
4		2
0		1
— 4	2	1
— 8	1	2
— 12	2	3
— 16		1
— 20	5	1
— 24	1	
— 28	2	
— 32	1	1
— 36		1
— 40	3	
— 44		
— 48	1	
— 52	2	
— 56		
— 60	1	
	21	18

r = .7387

Crampton test

	B	A
100	2	
95		
90	3	3
85		1
80	1	1
75	1	5
70	3	
65	3	1
60	2	2
55	1	2
50	3	
45	1	1
40		1
35	1	1
	21	18

r = .0101

McCurdy test

	B	A
24		1
21	1	1
18	1	1
15	3	1
12	6	5
9	5	3
6	1	5
3	2	
0	1	
— 3		
— 6	1	
— 9		
— 12		1
	21	18

r = .1502

Foster test

	B	A
15	12	6
14		2
13	4	6
12	3	
11	1	2
10		
9		
8		2
7	1	
	21	18

r = .1928

Schneider test

	B	A
15	1	2
14	3	1
13	1	3
12	1	3
11		2
10	1	3
9	2	2
8	4	1
7	1	1
6	1	1
5		
4	1	1
3	4	
2		
1		
0		
— 1	1	
	21	20

r = .4140

Derivation of formula for correlation by the method of "bi-serial r."

The derivation of a formula for this method of correlation was first presented by Karl Pearson*.

A simpler derivation is presented herewith.

Let us assume that there are two groups of individuals, one "not in good condition" (Group I) and one "in good condition" (Group II). These are represented as falling in an elliptical distribution in the accompanying figure. In this method, it is assumed that this variable of "condition" (X) has a "normal" or binomial distribution of the type described by the formula:

$$y_x = y_0 e^{\frac{-x^r}{2\sigma^2}}. \qquad \text{(a)}$$

Where y_x = any ordinate,

y_0 = the ordinate at the mean,

x = the *deviation* of the X variable from the mean of the distribution,

σ = the standard deviation of the X variable,

e = 2,7183.........

This *distribution* of the X variable is represented by the curve drawn below the rectangle.

In the diagram, (S) is the point which represents the intersection of the mean ordinate ($\bar{y}_1$) of the segment of the ellipse to the left of the line dividing the group, and of the mean abscissa ($\bar{x}_1$) of the same section of the distribution. The point (t) represents the corresponding point of Group II.

The line (b_{yx}), wich runs through these points and the means of both X and Y of the whole distribution, is the regression line of the ellipse. The slope of this line is:

$$b_{yx} = \frac{\bar{y}_2}{x_2} = \frac{\bar{y}_1}{x_1} = \frac{\bar{y}_2 - \bar{y}_1}{x_2 - x_1}. \qquad \text{(b)}$$

$$\text{Since } b_{yx} = r_{yx}\frac{\sigma_y}{\sigma_x}, \qquad \text{(c)}$$

$$r_{yx} = b_{yx}\frac{\sigma_x}{\sigma_y} \qquad \text{(d)}$$

$$= \frac{y_2 - y_1}{x_2 - x_1}\cdot\frac{\sigma_x}{\sigma_y} \qquad \text{(e)}$$

$$= \frac{\dfrac{y_2 - \bar{y}_1}{\sigma_y}}{\dfrac{x_2 - x_1}{\sigma_x}}. \qquad \text{(f)}$$

$$\text{But } \frac{y_2 - y_1}{\sigma_y} = \frac{\bar{Y}_2 - \bar{Y}_1}{\sigma_y}. \qquad \text{(g)}$$

* On a new method of determining correlation between a measured character A, and a character B, of which only the percentage of cases where no space in B exceeds (or falls short of) a given intensity is recorded for each grade of A. by Karl Pearson, F. R. S., Biometrika, Vol. 7, pp. 96—105. 1910.

Let (p) = proportion of individuals in Group I, and
(q) = proportion in Group II.
Then $p + q = 1$.
It can be shown that *in the normal distribution*

$$\frac{\bar{x}_1}{\sigma} = \frac{\sigma_{z_1}}{p} \tag{h}$$

and

$$\frac{\bar{x}_2}{\sigma} = \frac{\sigma_{z_2}}{q}. \tag{i}$$

Where (z) is the ordinate at the division between Groups I and II. Where, as in the X variable we assume a normal distribution of unit area and unit standard deviation, these become

$$-\frac{z}{p} \quad \text{and} \quad \frac{z}{q}. \tag{j}$$

Therefore,

$$\frac{\bar{x}_2 - \bar{x}_1}{\sigma} = \frac{\bar{x}_2}{\sigma} - \frac{\bar{x}_1}{\sigma} = \frac{z}{p} + \frac{z}{q} = \frac{z(p+q)}{pq} = \frac{z}{pq}. \tag{k}$$

The final formula, substituting formulae for (g) and (k) in formula (f) is:

$$\frac{\dfrac{\bar{Y}_2 - \bar{Y}_1}{\sigma_y}}{\dfrac{z}{p} + \dfrac{z}{q}} = \frac{\bar{Y}_2 - \bar{Y}_1}{\sigma_y} \cdot \frac{pq}{z}. \tag{l}$$

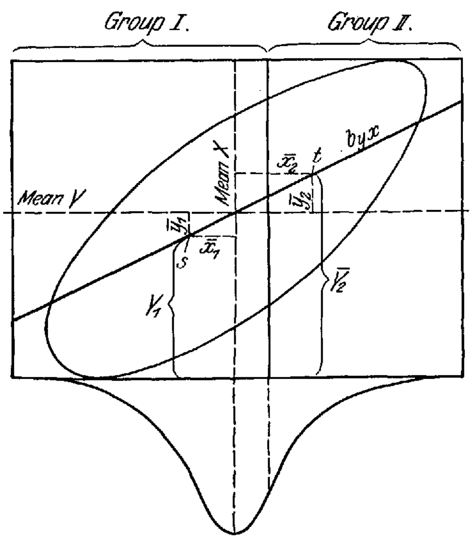

Fig. 1. In this diagram and throughout this paper capital letters, as X and Y represent deviations from 0. Lower case letters, as x and y represent deviations from their respective means. $\bar{Y}_1$, $\bar{Y}_2$ represent the means of the distributions of Groups I and II respectively.

In this formula (1),

($\bar{Y}_1$) is the mean of the (Y) distribution of Group I.

($\bar{Y}_2$) is the mean of the (Y) distribution of Group II.

(σ_y) is the standard deviation of the *whole* (Y) distribution, that is Groups I and II combined.

(z) can be ascertained from numerous table such as Table II in "Tables for Statisticians and Biometricians," *Karl Pearson*, 2nd edition, Cambridge University Press, 1924.

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