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Prediction Formulae for the Auricular Height and the Cranial Capacity of the Chinese Skull.

By Y. Yen and K. T. Ho

1. Introductory.
2. Brief notes on the material.
3. Notes on the methods of measuring the characters concerned.
4. Notes on the regression equations.
5. Tables for the measurements forming the bases of the formulae.
6. Tables for the prediction formulae.

Introductory: In cephalometry most of the difficulty encountered is to take the two fundamental measurements, i. e., the auricular height, especially on the living, and the cranial capacity on the deceased cranium. It is because not only the error of personal observation and instruments is great but the methods are also likely to give a great divergence of differences in the experience of various authors. So various formulae have been devised by physical anthropologists to calculate the auricular height (1) and cranial capacity (2 & 3).

Justav Fisher provides five tables which facilitate the calculation of auricular height or head height from two measurements. The measurem-

(1) Justav Fisher: Jena, 1932; *American Anthropologist*, Vol. 36, 1934.

(2) Lee and Pearson: "On the Reconstruction of the Capacity of the Skull from External Measurements," *Philosophical Transaction*, London, Vol. CXCVI, pp. 225-264.

(3) T. Wingate Todd: "Mathematical Calculation of Cranial Capacity," *Amer. Jour. Phys. Anthrop.*, Vol. VI, 2, pp. 188-191.

ents are tragion to tragion and bregma to tragion. The formula from which height is reckoned.

$$\sqrt{(t-b)^2 \div \left(\frac{t-t}{2}\right)^2}$$

Lee and Pearson were the first to introduce the intraand inter racial formulae for the estimated capacities of various races. The constants they used are the product of three principal diametral or arcual measurements (4).

With regard to the auricular height, the formula $\sqrt{(t-b)^2 \div \left(\frac{t-b}{2}\right)^2}$, since it contain bregma, which is almost impossible to find accurately on the living, as stated by Professor A E. Hooton, is rather used with restriction in cephalometry.

No similar attempt to estimate the capacity of the Chinese skull had been made till recently Dr T L. Woo who has been making such a study will soon publish his results The object of the present study is to provide the adequate formulae based on a long series of skull available and on some characters which can be used on the living for auricular height, and simultaneously for the cranial capacity. These formulae are expected to be correct with certain limitations i.e., the same race, the same region and the same period, when it is used to deal with the population concerned.

Brief notes on the material: The present material treated consists of 1226 male and 274 female Chinese crania collected by the Department of Anatomy, College of Medicine and Dentistry, W.C.U.U.. A few of them were collected in the dissecting room, the majority of them were from the old graves destroyed in a city planning project. These specimens are presumably the Chinese who probable were the natives of the province of Szechwan during the recent generation. The juvenile and pathological specimens are all excluded. So the present material represents approximately the normal modern adult Chinese or Szechwanese.

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(4) The same constants will be used to construct the prediction formulae for the cranial capacity in the second paper dealing with the same problem.

Notes on the methods of measuring the characters concerned.

(1) Maximum length (ML): the greatest diameter of the skull measured from the glabella with the spreading compass one branch of the latter being fixed at the glabella while with the other the greatest length is sought.

(2) Maximum breadth (MB): the greatest horizontal breadth of the cranial vault measured with the Flower's craniometer.

(3) Auricular height (AH): the vertical height of the cranial vault above the interporial plane taken with a craniostat (5) which was devised by T. Wingate Todd and his method is strictly followed. (The skull being oriented on the craniostate in the Frankfort Plane, the measurement was taken with care.)

(4) Horizontal circumference (HC): the greatest cranial circumference measured in one horizontal plane with a steel tape passing in front just above the supraorbital ridges and behind over the most prominent part of the occiput.

(5) Cranial capacity (C): this was measured with seed, and the method of Macdonell (6) was strictly followed. (One standard skull of which the average water capacity is 1250 cm^3, was used all the time in comparison and checking the individual result.)

Notes on the regression equations.

The method used for prediction is that of regression formulae. The regression coefficients figuring in such formulae are based on predetermined measures of the degrees of correlation existing between the respective known and unknown characters.

The characters selected here for constructing the formulae for auricular height are the maximum height, maximum breadth, and horizontal circumference, and for the cranial capacity are the maximum height, maximum breadth, auricular height, and horizontal circemference. The reason is chiefly on account of their relationship close to the auricular height and the capacity respectively and vice versa.

The means, standard deviation, and correlation coeffecients of the characters under consideration, upon which the resulting formulae are based, are given in tables 1 – 4:

The simple regression formulae for anriculae for auricular height for both sexes are listed in tables 5 and 5, and for cranial capacity in tables 7 and 8, and the multiple regression formulae for auricular height are listed in tables 9, and 10, and fot cranial capacity in tables 11, and 12.

(5) *A. J. Physical Anthropology*, Vol. VI, 1923, pp. 46-149.

(6) *Biometrika*, Vol. III, 1940, pp. 191-244.

TABLE 1.

Measurements forming the bases of the formulae for auricular height (male).

Measurements	No.	Mean	Standard deviation	Correlation Coefficients			
				ML	MB	AH	HC
Maximum length (ML) in mm.	1203	180.93	6.39	1	0.133	0.404	0.842
Maximum breadth (MB) in mm.	1204	137.65	5.44	0.136	1	0.411	0.507
Auricular height (AH) in mm.	1203	115.64	4.42	0.404	0.411	1	0.485
Horizontal circumference (HC) in mm.	1207	515.93	16.11	0.842	0.507	0.485	1

TABLE 2.

Measurements forming the bases of the formulae for auricular height (female).

Measurements	No.	Mean	Standard deviation	Correlation Coefficients			
				ML	MB	AH	HC
Maximum length (ML) in mm.	271	175.37	5.94	1	0.636	0.515	0.77
Maximum breadth (MB) in mm.	273	134.00	2.76	0.636	1	0.475	0.43
Auricular height (AH) in mm.	271	112.51	4.18	0.515	0.475	1	0.69
Horizontal circumference (HC) in mm.	270	497.55	14.04	0.770	0.433	0.434	1

TABLE 3.

Measurements forming the bases of the formulae for cranial capacity (male)

Measurements	No.	Mean	Standard deviation	Correlation Coefficients				
				CC	ML	MB	AH	HC
Cranial capacity (CC) in cm^3.	1221	1413.08	121.51	1	0.593	0.549	0.559	0.737
Maximum length (ML) in mm.	1203	180.93	6.390	0.593	1	0.136	0.404	0.842
Maximum breadth (MB) in mm.	1204	137.65	5.440	0.549	0.136	1	0.411	0.507
Auricular height (AH) in mm.	1203	115.64	4.420	0.559	0.404	0.411	1	0.485
Horizontal circumference(HC) in mm.	1207	515.96	16.110	0.737	0.842	0.507	0.485	1

TABLE .4

Measurements forming the bases of the formulae for cranial capacity (female)

Measurements	No.	Mean	Standard deviation	Correlation Coefficients				
				CC	ML	MB	AH	HC
Cranial capacity (CC) in cm^3.	224	1283.93	109.20	1	0.601	0.515	0.698	0.727
Maximum length (MB) in mm.	271	175.37	5.940	0.601	1	0.626	0.515	0.770
Maximum breadth (MB) in mm.	273	134.00	2.760	0.515	0.636	1	0.475	0.433
Auricular height (AH) in mm.	271	112.51	4.18	0.698	0.515	0.475	1	0.434
Horizontal circumference (HC)in mm	270	49 .55	14.04	0.727	0 770	0.433	0.434	1

TABLE 5.

Simple Regression formulae for auricular height (male) (7)

Prediction of	From known measurements of	Formulae
(1) Auricular height	Maximum length	AH=0.609 ML+ 9.777 ($\pm 4.005\sqrt{n}$)
(2) Auricular height	Maximum breadth	AH=0.506 MB+45.789 ($\pm 2.612\sqrt{n}$)
(3) Auricular height	Horizoatal circumference	AH=1.768 HC−796.577 ($\pm 6.042\sqrt{n}$)

TABLE 6.

Simple regression formulae for auricular height (female)

Prediction of	From known measurements of	Formulae
(4) Auricular height	Maximum length	AH=0.363 ML+ 48.851 ($\pm 2.416\sqrt{n}$)
(5) Auricular height	Maximum breadth	AH=0.221 MB+ 82.896 ($\pm 1.639\sqrt{n}$)
(6) Auricular height	Horizontal circumference	AH=1.768 HC−796.577 ($\pm 9.508\sqrt{n}$)

(7) The formulae for auricular height, if used on the living, should be corrected in some respects, and this shall be given in the second paper dealing with this problem

TABLE 7.

Simple regression formulae for cranial capacity (male).

Prediction of	From known measurements of	Formulae	
(7) Cranial capacity	Maximum length	$C=0.021+1409.33$	$(\pm 3.420\sqrt{n})$
(8) Cranial capacity	Maximum breadth	$C=0.025+1409.69$	$(\pm 30.71\sqrt{n})$
(9) Cranial capacity	Auricular height	$C=0.020+1410.73$	$(\pm 2.477\sqrt{n})$
(10) Cranial capacity	Horizontal circumference	$C=0.098+1362.67$	$(\pm 7.345\sqrt{n})$

TABLE 8.

Simple regression formulae for cranial capacity (female).

Prediction of	From known measurements of	Formulae	
(11) Cranial capacity	Maximum length	$C=0.033ML+1283.93$	$(\pm 3.109\sqrt{n})$
(12) Cranial capacity	Maximum breadth	$C=0.016MB+1281.77$	$(\pm 1.363\sqrt{n})$
(13) Cranial capacity	Auricular height	$C=0.020AH+1281.71$	$(\pm 2.416\sqrt{n})$
(14) Cranial capacity	Horizontal circumference	$C=0.099HC+1234.67$	$(\pm 6.042\sqrt{n})$

TABLE 9.

Multiple regression formulae for auricular height (male)

Prediction of auricular height From known measurements of :	
(15) Maximum length and Maximum breadth	$AH = 0.252\ ML + 0.314\ MB + 25.173\ (\pm 2.822\sqrt{n})$
(16) Maximum length and Horizontal circumference	$AH = 0.069\ ML + 0.121\ HC + 51.507\ (\pm 3.698\sqrt{n})$
(17) Maximum breadth and Horizontal circumference	$AH = 0.196\ MB + 0.102\ HC + 55.991\ (\pm 2.543\sqrt{n})$

TABLE 10.

Multiple regression formulae for auricular height (female).

Prediction of auricular height From known measurements of :	
(18) Maximum length and Maximum breadth	$AH = 0.252\ ML + 0.372\ MB + 13.310\ (\pm 2.698\sqrt{n})$
(19) Maximum length and Horizontal circumference	$AH = 0.031\ ML + 0.009\ HC + 102.743\ (\pm 2.604\sqrt{n})$
(20) Maximum breadth and Horizontal circumference	$AH = 0.534\ MB + 0.099\ HC - 8.160\ (\pm 2.785\sqrt{n})$

TABLE 11.

Multiple regression formulae for cranial capacity (male)

Prediction of cranial capacity From known measurements of:		
(21) Maximum length and Maximum breadth	$C = 10.021\ ML + 11.637\ MB - 2000.850$	$(\pm\ 80.006/\sqrt{n})$
(22) Maximum length and auricular height	$C = 8.374\ ML + 10.592\ AH - 1327.010$	$(\pm\ 79.984/\sqrt{n})$
(23) Maximum breadth and auricular height	$C = 8.626\ MB + 10.966\ AH - 1042.354$	$(\pm\ 82.443/\sqrt{n})$
(24) Maximum length and Horizontal circumference	$C = 1.670\ ML + 6.263\ HC - 2120.425$	$(\pm 101.783/\sqrt{n})$
(25) Maximum breadth and Horizontal circumference	$C = 5.396\ MB + 4.595\ HC - 1700.495$	$(\pm\ 94.080/\sqrt{n})$
(26) Auricular height and Horizontal circumference	$C = 7.307\ AH + 4.606\ HC - 1808.554$	$(\pm\ 93.421/\sqrt{n})$

TABLE 12.

Multiple regression formulae for cranial capacity (female)

Predicton of cranial capacity From known measurements of:		
(27) Maximum length and Maximum breadth	$C = 9.708\ ML + 10.131\ MB - 1776.29$	$(\pm\ 66.362/\sqrt{n})$
(28) Maximum length and auricular height	$C = 9.063\ ML + 13.817\ AH - 1859.960$	$(\pm\ 73.654/\sqrt{n})$
(29) Maximum breadth and auricular height	$C = 9.312\ MB + 15.238\ AH - 1678.255$	$(\pm\ 83.524/\sqrt{n})$
(30) Auricular height and Horizontal circumference	$C = 12.238\ AH + 5.061\ HC - 2119.625$	$(\pm\ 74.243/\sqrt{n})$
(31) Maximum length and Horizontal circumference	$C = 1.897\ ML + 5.044\ HC - 1558.493$	$(\pm\ 82.345/\sqrt{n})$
(32) Maximum breadth and Horizontal circumference	$C = 9.750\ MB + 4.814\ HC - 2431.349$	$(\pm\ 81.535/\sqrt{n})$

推測中國人顱骨顱高及容量之公式

顏　閻　何光篪

吾人測量顱骨時，於顱高（在量活體時尤甚）及容量二種基本工作，常感困難，其原因爲個人觀察之錯誤，及儀器不同與夫應用法則之差異。故一般人類學家曾製定公式，以求應用之簡便，及錯誤之減少。然此類公式，每只限用於某一民族或數民族。茲爲應用於中國人計，特推定公式如前。公式分簡複兩種：簡種用於已知測量之一，複種用於已知兩種。

本文所述公式係由測量中國四川近代顱骨（計男性 1226，女性 274）後推算而得，故應用於時間相同，區域年代相近之種族，最爲相宜。

VERBAL DIRECTIVE PREFIXES IN THE JYARUNG LANGUAGE AND THEIR CH'IANG EQUIVALENTS

By Wen Yu

Some ten years ago, Stuart N. Wolfenden, the late English student, in his stimulating work, *Outline of Tibeto-Burman Linguistic Morphology*[1], maintained a theory that the Proto-Tibetan possessed a directive infix in its verbal mechanism. It indicates that the so called superadded consonants *r-*, *l-* and *s-* and possibly the so-called prefixes *d-* and *g-* served directive functions in their original forms. But this is merely a hypothesis. No evidence can definitely prove it, so the question is still open to further discussion.

Now, the writer desires to point out a really directive element from our kindred language. This will not be an infix but a prefix. Also this will not be in Proto Tibetan but in its younger cousin the Jyarung. Moreover, this will not show *to, into, towards, in, on, upon* and *against* as Wolfenden imagined[2] but *up* and *down*, and *forward* and *backward* from the speaker's standpoint.

Jyarung, a most curious language in the Sino-Tibetan family, is very little known to us. Since the days of B. H. Hodgson[3] and Terrien de Lacouperie[4] we have made but little progress concerning it yet, although a lengthy essay dealing with the *K'am-to* dialect has recently been reported

(1) Published by the Royal Asiatic Society, Price Publication Fund Vol. XII, London, 1929.

(2) *Op. cit.* p. 38.

(3) "Tribes of Northern Tibet and Sifan", *J. A. S. B.* Vol. XXII, 1852, also in his book *On the Languages, Literature and Religion of Nepal and Tibet*, pt. II, 1874. Owing to the rarity of these publications, the writer got some information from Terrien's work only.

(4) *The Languages of China before the Chinese*, §130-135.

by Wolfenden,[5] of which the particular phenomenon in question has not been considered at all.

There are four prefixes *tə*, *na*, *ko* and *də* used before the verb root in the Paslok dialect[6] of the Jyarung language, which have a definite influence on the meaning of the simple verb, thus:

tə	implies motion upward.
na	implies motion downward,
ko	implies motion forward,
də	implies motion backward.

So we can easily find the conflict if certain verbs and certain prefixes are joined. Some limitations therefore naturally obtain. e. g.

(1) Some verbs can only be preceded by a certain prefix, such as (a) *k'as*[7] 'to be angry', *nəs* 'to be anxious', *np'ər* 'to envelope', *nga sum* 'to awake' and *ptso* 'to use' with these the only prefix used is *tə*; (b) *lat* 'to write', *jo* 'to hang', *rzak* 'to tread', *sn̥m ts'ou* 'to dye' and *Tiep* 'to roll, to fall' with these the only prefix used is *na*; and (c) *məs* 'to forget' and *ciət* 'to close' are only used with *də* as prefix.

(2) Although it is true that some verbs can be controlled by two or more prefixes, conflict still occurs sometimes as in *shii* 'to die'; this can be prefixed with *na* or *də*, but the *ko* must be excepted. Besides, *skie* 'to

(5) "Notes on the Jyarung Dialect of Eastern Tibet', *TP.* Vol. XXXII, 1936.

(6) For this name, see writer's previous article "The Personal Endings of the Verb in the Jyarung Language as Spoken at Paslok", *SS.* Vol. I, no. 4, 1940.

(7) Although the Jyarung verbs seem to have infinitive prefixes as the writer described in previous article, their exact functions are still obscure. So we would rather omit them here.

cook', *rji* 'to laugh' are limited to *ko* or *na*, while *wa niet* 'to burn', *rkuak* 'to embrace', *zii* 'to tell' are limited to *ko* or *ta*.

3) Even if a verb can be preceded by all the prefixes cited above, its meaning when preceded by a certain prefix, may still be readily influenced, thus: *ji* 'to go', while *ngo ta jing* means 'I went upward', *ngo na jing* means 'I went downward', *ngo ko jing* means 'I went forward' and *ngo da jing* means 'I went backward'.

(4) If a verb possesses a wide meaning, it may diverge towards different words, as represented in other languages, following the different prefixes used. For instance *pie* will mean 'to weave'[8] when it is preceded with *ko* or 'to read' with *na*; *cie* will mean 'to take' with *ta* or 'to receive' with *da*; and *rngie* will mean 'to lend to' with *ko* or 'to borrow from' with *da*.

Similar varieties are to be found in the neighboring language the Ch'iang (羌). Since it is known that the Ch'iang possessed many dialects, the writer will confine his illustrations to some of them. First, to take the Li-ping (理坪) dialect, which belongs to the Group I and case-dialects in the writer's classification[9], thus:

te	implies motion upward,
hhen	implies motion downward,
she	implies motion outward (also forward),
ji	implies motion inward (also backward).

We can also easily find the natural connections between the verbs themselves and their prefixes, as in the following examples.

(8) Although the prefixed verbs always represent the past tense, for the facility of explanation, we still interpret them as infinitives here.

(9) See another article of the writer "A Tentative Classification of the Ch'iang Language in Northwestern Szechwan", *SS*. Vol. II, 1941.

(1) We understand that some verbs must be preceded by *te*, and that the others must be preceded by *hhen*, *she* or *ji*. I *p'i* 'to thank', *zi* 'to stand up', *tui* 'to carry on the shoulder with a pole', *x* 'to eat enough', *hlu* 'to break asunder', the usual prefix is *te*; in *be* 'to cover, to inter'; *le ji* 'to bury', *hle* 'to place down', *kwe* 'to build', the usual prefix is *hhen*; in *gu lia* 'to excavate, to dig', *pu* 'to blow', *tsqu* 'to cut off', *hle* 'to see a person off', the usual prefix is *she* while in *xxe* 'to pick', *di* 'to welcome' the usual prefix used is *ji*.

(2) Indeed, in some verbs the use of these prefixes is comparatively free; but this freedom is still confined within reasonable limits. For instance *ga* 'to pick up, to take', *ze* 'to support', these mean nothing except with *te* or *ji* while *chwa* 'to shoot', *pe* 'to blossom' are meaningless except with *te* or *she*.

(3) Also the direction of a verb can be changed with the use of different prefixes. For instance *sche* means 'to point', while *te sche* means 'to point upward', *hhen sche* 'to point downward', *she sche* 'to point outward' and *ji sche* 'to point inward'.

(4) The meaning of a verb can also be changed when different prefixes are used. For instance *gu* means 'to wear up' with the prefix *te* or 'to lose' with *she*: *hlo* means 'to undress' with the prefix *she* or 'to fall' with *hhen* and *stue* means 'to receive' with the prefix *ji* or 'to pluck up' with *te*.

A second illustration is the Lo-lu-chai (羅勒寨) dialect, which is Group II of the writer's classification and a caseless dialect. Its verbal prefixes are as follows:

tu	implies motion upward,
hha	implies motion downward,
sii	implies motion outward (also forward),
je	implies motion inward (also backward),