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Cranial Capacity: New Caucasian Data and Comments on Rushton's Claimed Mongoloid–Caucasoid Brain-Size Differences

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There appears to be little published information for modern humans on the relation between body weight (WT) and brain weight or size (cranial capacity, CC). We present data on WT, stature, head measurements, and calculated CC from 211 young adult Caucasian male students. In this sample the correlation between WT and CC is +.202 ($p < .01$) and the value of b in the usual equation, CC = $a(\text{WT})^b$ is .087 ± .030 (*SE*).

Rushton (1991a) presented data on WT and calculated CC from 4 Mongoloid (M) and 20 Caucasoid (C) samples of military men ($N = 57{,}378$). Using the value $b = .67$ (derived from *between*-species comparisons), Rushton (1991a) claimed that, after correcting for the (lower) mean WT of M, the enecephalization quotient (and, therefore, CC) for M exceeds that of C. However, when the covariance adjustment for WT is made using a b value of either the preceding .087 or .200 (3.8 *SE*s above .087), and sample means are weighted by sample size (not done by Rushton, 1991a), the mean CC value of the M remains very significantly below that of the C. Only when b reaches .400 do the two adjusted means approach each other. We conclude that these military data do not support Rushton's (1991a) claim for a greater WT-adjusted CC of M. We also suggest that in modern humans, other factors, such as speed and efficiency of cortical information processing, may be more important for intelligence than brain size.

Rushton (1991a) presented extensive data (his Table 1) on body weight (WT), head measurements, and calculated (estimated) cranial capacity (CC) from 4 Mongoloid (M) and 20 Caucasoid (C) male military samples. Each sample was represented only by a sample size and measurement means, but the sample sizes were large (usually over 1,000) and the total number of men was 57,378. The unweighted overall means for both CC and WT of the M are less than those of C.

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Rushton (1991a) stated that he calculated the "excess" brain tissue, the encephalization quotient (EQ), for the 24 samples from the equation

$$EQ = CC\ (\text{in cm}^3)/(0.12)(WT\ \text{in gm})^{.67}$$

and found a significantly higher mean value for M. This formula is due to Jerison (1973), and was designed to express the relationship between CC and WT when comparing different vertebrate groups. Higher values of EQ are said to show mental capacity above and beyond body "housekeeping" demands; monkeys have a higher EQ than dogs, great apes are higher than monkeys, and humans (and dolphins) are the highest of all.

The value .67 in the preceding equation is b in the equation $CC = a(WT)^b$ or, equivalently, $\log(CC) = \log(a) + b \log(WT)$, (e.g., Jerison, 1982, p. 767; Pagel & Harvey, 1989). Willerman (1991) criticized Rushton's (1991a) conclusion on several grounds, including the use of the value .67 for the exponent b, arguing that this value is only for use *between* different taxonomic groups, whereas Rushton was working within one species. Rushton (1991b) defended his use of .67 even though he quoted Jerison (1990) as saying that the *within*-species value of b may fall to zero; Pagel and Harvey (1989), whom Rushton (1991a) quoted, also said that b may become very small or zero for within-species comparisons.

Rushton (1991a) used his 24 sample means as if each were 1 individual. The great range in sample sizes, 100 to 9,414, is not reflected in his analysis, nor is the fact that the data actually came from 57,378 individuals.

There appears to be a surprising lack of information in humans on the relation between calculated CC and WT as represented by the value of b. Neither Rushton (1991a, 1991b) nor Willerman (1991) referred to any human studies giving an estimate for b. A study by us on intelligence, electrophysiological factors, and reaction time in young adult male Caucasians (Jensen & Reed, 1990; Reed & Jensen, 1991, 1992, 1993) also collected data on body and head measurements. We present these data, calculating CC on 211 of these subjects and determining the relation between CC and WT to find the value of b in this population. The value is low. Using this value and selected higher values of b with the 24 samples of Rushton (1991a), we adjusted CC for WT and calculated the weighted overall mean values of CC for M and C. We do not confirm Rushton's (1991a) conclusion that, after correcting for body size, CC for M exceeds that of C.

SUBJECTS AND METHODS

Subjects

The subjects were students from three postsecondary educational institutions in the eastern San Francisco Bay region of California; 122 were from a university and 89 were from two community colleges (2-year institutions accepting any high school graduate). All were male, between 18 and 25 years of age, of European ancestry, and in apparent good health.

Methods

The subjects were measured for stature and weight; head length and head breadth were determined with a cephalometer caliper and head height was measured with a Todd head spanner (Olivier, 1969). CC was calculated by the Lee and Pearson (1901) formula for men:

$$CC = .000337(L - 11)(B - 11)(H - 11) + 406.01$$

where L, B, and H are length, breadth, and height, respectively, of the head, all measured in millimeters. This is the formula used by Rushton (1991a).

The university students were given the Raven's Advanced Progressive Matrices intelligence test (Raven, 1983a); the college students were given the Standard Progressive Matrices version (Raven, 1983b). These tests were given without time limit; most students took between 30 and 60 min. For comparability, the Raven scores were converted to equivalent Otis-Lennon IQ scores (general population, $M = 100$, $SD = 16$; Jensen, Saccuzzo, & Larson, 1988).

Correlations among CC, stature, and weight, both untransformed and as $\log_{10}$ values, were calculated. Stepwise regression of $\log_{10}$ (CC) on $\log_{10}$ (WT) and $\log_{10}$ (stature) was performed, with probability for entry set at .05. Because only $\log_{10}$ (WT) entered the regression, its regression coefficient is the exponent b.

Overall mean values for Mongoloids (from the 4 samples), Caucasoids (from the 20 samples), and the total (24 samples) were calculated for CC and weight, both unweighted and weighted by sample size. The total weighted mean for WT was 68.03 kg. Each of the 24 samples was standardized to this weight for four different values of b to obtain the standardized (WT-adjusted) CC value (CC: 68.03 kg, b), which would result if the sample mean WT were 68.03 kg and b correctly related CC to WT. This standardization is a covariance adjustment of a dependent variable, CC, for the effect of an independent covariate, WT, as is done in standard analysis of covariance (ANCOVA; e.g., Snedecor & Cochran, 1980, pp. 365–367). The standardized $\log_{10}$ (CC) is given by

$$\log_{10} (\text{CC: } 68.03 \text{ kg}, b) = \log_{10} (\text{CC}) - b \log_{10} (\text{WT}/68.03)$$

where (CC) is the unstandardized calculated value in cm^3, (CC: 68.03 kg, b) is CC standardized to 68.03 kg and a value of b, and WT is in kg (e.g., see Snedecor & Cochran, 1980, p. 367). The values of b used were .087334 (from the previous regression), .200, .400, and .450; the reason for the three latter values will become clear. The antilog standardized CC values are reported.

RESULTS

The mean age of the 211 students in this report was 20.32 ± 0.14 (± *SE*) years (*SD* = 2.00 years). The means and standard deviations for the body and head measurements, calculated CC, and IQ are given in Table 1. For a test of homogeneity across IQ levels, these data are also given for three IQ levels: 60 subjects with IQs between 87 and 111 inclusive, 75 with IQs 112 to 123, and 76 with IQs 124 to 136. Excepting IQ, none of the means differ significantly among the three levels. The mean values of the measurements, based on the total of 211, agree reasonably well with the values of the taller of the 10 American Caucasian samples of Rushton's (1991a) Table 1. The students' mean stature, 178.4 ± 0.51 cm, appears greater than any American mean but probably not significantly so. The students' mean WT, 74.4 ± 0.73 kg, is in the range of the American means. The students' means for head length, 200.0 ± 0.43 mm, and head height, 139.8 ± 0.46 mm, are significantly greater, and their head breadth, 150.8 ± 0.37 mm, is significantly less than the corresponding means of most American samples.

The students' mean calculated CC, 1554 ± 6.6 cm^3, appears to exceed all but 1 (Rushton, 1991a, "100 U.S. Divers, 1972": 1589 cm^3) of the 10 American sample CC means. In estimating the significance of the CC mean differences, we note that the students' CC standard deviation of 95.6 corresponds to a 99% confidence interval of 81.3–116.6 (Pearson & Hartley, 1962, Table 35). Taking 120 for a conservative upper limit for the standard deviation gives a *maximal* standard error of 8.3 for the student mean CC. Using a standard deviation of 120, the second highest American sample mean CC, 1539 cm^3 for "2,420 U.S. Air Force, 1967" (Rushton, 1991a) men, would have a standard error of about 2.4, indicat-

TABLE 1
Anthropometric Variables and IQ Scores in 211 Caucasian Students[a]

IQ Level[b]	*N*	Head Length (mm)	Head Breadth (mm)	Head Height (mm)	Stature (cm)	Weight (kg)	Cranial Capacity[c] (cm^3)	IQ[d]
1	60	199.4	150.8	139.8	179.3	75.8	1550	105.2
		(6.81)	(5.08)	(6.03)	(6.45)	(10.74)	(94.8)	(5.12)
2	75	200.7	151.2	140.1	178.3	74.8	1563	118.5
		(7.00)	(5.83)	(7.11)	(8.31)	(10.83)	(99.5)	(3.12)
3	76	199.8	150.5	139.7	177.9	72.9	1549	129.9
		(4.97)	(5.18)	(6.80)	(7.35)	(10.38)	(92.8)	(3.86)
Total	211	200.0	150.8	139.8	178.4	74.4	1554	118.8
		(6.27)	(5.38)	(6.68)	(7.46)	(10.66)	(95.6)	(10.64)
SE[e]		0.43	0.37	0.46	0.51	0.73	6.6	0.73

[a]Means and (standard deviations). There are no significant differences among IQ levels for any variable other than IQ.
[b]Level 1 = 87–111; Level 2 = 112–123; Level 3 = 124–136.
[c]Calculated from head measurements (see text).
[d]Otis-Lennon equivalent of Raven Progressive Matrices score (see text).
[e]Standard errors for total population.

ing a nearly significant difference. The third highest American CC mean, 1502 cm^3, is very significantly lower than the students' mean.

The CC standard deviation 95.6, agrees well with the observed variation in WT according to the criterion of Pagel and Harvey (1989, Note 9): They found that, *within* mammalian species, the ratio of brain-weight variance to body-weight variance is .19; R.L. Holloway (quoted in Pagel & Harvey) found an average ratio of .18 within 11 primate species. For the 211 students, this ratio is .184 (calculated as the ratio of squared coefficients of variation in order to give a dimensionless number). This indicates good agreement with other mammalian and primate species, and that the observed standard deviation is reasonable. The students' CC values range from 1235 cm^3 to 1883 cm^3 and the distribution is normal (no suggestion of skewness or kurtosis). Both of these extreme values occur in university students; the student with the lower value has an IQ of 127, and the upper value is associated with an IQ of 123. Similarly, students in the two extreme 5% tails of the CC distribution (9 cases below the 5th percentile, 12 cases above the 95th percentile) do not differ in mean IQ. Those in the lower tail have a mean IQ of 114.8 and those in the upper tail have a mean of 116.5 (t = .35).

The correlation between CC and IQ in the students is very low and nonsignificant, +.015 ($p = .83$). Table 2 gives the correlations among stature, WT, and CC for untransformed values and for $\log_{10}$ values. This transformation has very little effect on correlation. CC correlates slightly more with WT (.202, $p < .01$) than with stature (.182, $p < .01$).

Stepwise regression of $\log_{10}$ (CC) on $\log_{10}$ (stature) and $\log_{10}$ (WT), with p for entry into the regression set at .05, included only WT. The regression coefficient, which is b, is .087334 ± .029662 ($p = .0036$); $R = .200$, $R^2 = .0398$, adjusted $R^2 = .0352$; partial r (corrected for WT) for $\log_{10}$ (stature): $\log_{10}$ (CC) is .090 ($p = .19$). The regression equation is

$$\log_{10} (\text{CC in cm}^3) = 3.027655 + .087334 \log_{10} (\text{WT in kg})$$

The 99% confidence limit for b has an upper limit of .164.

Table 3 presents original (unstandardized) overall group means for WT and

TABLE 2
Correlations Among Stature, Body Weight, and Cranial Capacity in 211 Caucasian Students[a]

	Stature	Weight	Cranial Capacity
Stature	1	.518**	.182*
Weight	.538**	1	.202*
Cranial Capacity	.182*	.200*	1

[a]Correlations *above* diagonal are on untransformed values; correlations *below* diagonal are on $\log_{10}$(values).
*$p < .01$, two-tailed. **$p < .001$, two-tailed.

TABLE 3
Overall Mean Weight and Calculated Cranial Capacity of Mongoloid and Caucasoid Male Military Personnel[a]

Item[b]	Mongoloid	Caucasoid	Total
N	9,090	48,288	57,378
Weight (kg)			
Unweighted	57.41	72.87	70.30
Weighted	56.55	70.19	68.03
Cranial Capacity (cm³)			
Unstandardized			
Unweighted	1343	1467	1446
Weighted	1325	1448	1429[c]
Standardized (68.03 kg, *b*) and weighted			
b = 087334	1348	1445	1429[c]
.2000	1376	1440	1429[c]
.4000	1428	1431	1431[c]
.4500	1442	1429	1431[c]

[a]Based on data from Rushton (1991a, Table 1). Overall means from the 4 Mongoloid and 20 Caucasoid samples.

[b]Unweighted calculated from Rushton's (1991a) Table 1 means without weighting by sample size; weighted calculated from Rushton's (1991a) Table 1 by weighting each mean by its sample size. Unstandardized is based on original values; standardized (68.03 kg, *b*) is weighted mean calculated after standardizing each sample mean to 68.03 kg body weight, and adjusting the sample mean's cranial capacity accordingly with the value of *b* as described in the text.

[c]These are the same within the 4-digit accuracy used for the standard (Total) weight = 68.03 kg.

CC, both unweighted and weighted by sample size, for the 9,090 Mongoloids (M), 48,288 Caucasoids (C), and 57,378 total (T) of Rushton's (1991a) Table 1. Standardized (to 68.03 kg WT, for four values of *b*) and weighted (by sample size) mean values of CC for M, C, and T are also presented. Weighting slightly decreases the means for WT and CC in each group; after this weighting, a very appreciable WT difference, 13.64 kg, remains, showing the need to adjust (standardize) for this before comparing CC means.

The adjustment (standardization) for the effect of WT on CC, mediated through the value of *b*, raises the CC for M, decreases CC for C, and keeps the total mean CC constant (within 4-digit accuracy) at 1429 cm^3. Using the *b* value of .087334 from the students raises the M mean from 1325 to 1348 while reducing the C mean from 1448 to 1445; this adjustment decreases the difference from 123 to 97 cm^3, still very significantly different. (A maximal *SE* for the M mean is $120/(9{,}090)^{.5} = 1.26$; that for the C mean is .55; a difference between M and C means of about 4 cm^3 or more would therefore be significant.) Using a *b* value of .200 (well above the 99% confidence interval from the student sample) gives M and C means of 1376 and 1440, respectively, with a difference of 64 cm^3. Only when *b* is .400 do the M and C means approach each other, being 1428 and 1431, not significantly different. At $b = .450$ the M and C means are 1442 and 1429; the M mean is now significantly greater. This covariance adjustment for the effect of weight is linear; when CC is plotted against b separately for each race, the two lines intersect at $b = .41$. Mathematically, we can produce a wide range of (M − C) mean differences, negative or positive, by simply choosing appropriate b values. In the next section, however, we argue that biology sharply constrains the choice of b values.

DISCUSSION

It is clear that knowledge of the relation between WT and brain size (or head size) is necessary for any comparison of brain size among human groups differing appreciably in WT, as Mongoloids and Caucasoids do. In the apparent absence of reliable human data on this relation expressed in the value of the exponent b, the data presented here on 211 California Caucasian male students should be useful.

The general agreement of our anthropometric means and calculated cranial capacity with the taller American military means seems reasonable. The relative homogeneity of the men in our sample in their calculated CC means across widely different IQ levels underscores the near-zero correlation between CC and IQ in this sample. The role of weight as a predictor of CC is confirmed, but the correlation, .202, is low and, more importantly, so is the value of b: $.087 \pm .030$. This low value agrees with the views of Pagel and Harvey (1989) and Jerison (1990) for b values *within* mammalian species; it differs greatly from the value .67 used by Rushton (1991a). Because .67 comes from the work of Jerison (e.g., 1973, 1982) for *between*-species comparisons of vertebrates (often between high taxonomic categories: classes, orders, and families) and Rushton (1991a, 1991b) has not justified this high value, there seems to be no reason to accept his conclusions based on it.

For comparing (testing the null hypothesis of no difference) Mongoloids and Caucasoids for CC after adjusting for differences in WT, we used the preceding value, .087334, from our study and three extreme higher values. The next higher value, .200, is 3.77 standard errors above .087 ($p < .0001$); the values .400 and .450 would not occur in a Caucasian sample. Using b values of .087334 and .200 for making the covariance adjustment (standardization) for the different M and C WTs, and also weighting each sample mean by its sample size, as is done in the usual ANCOVA (each individual observation has equal weight), the overall mean CC for M is still far below the overall mean CC for C. Only when b is .400 ($4.6 \times .087344$) or higher does the CC mean for M reach or surpass the C mean.

It might be argued that our value for b is both a within-species and a within-race estimate, but what is required here is a within-species, *between*-race estimate. The question here is whether b for M is similar to that for C, or at least, is not more than two to four times greater. We feel that the burden of proof is on others to show a greater difference in *b* values. Consequently, we believe that the conclusion Rushton (1991a, 1991b) drew from these military data—that the WT adjusted CC of Mongoloids exceeds that of Caucasoids—is not correct.

The quite low correlation between WT and CC in our students raises the question of whether other physical factors may more importantly affect CC. For example, Beals, Smith, and Dodd (1984) studied 122 human populations distributed worldwide and presented extensive evidence that climate may be an important factor affecting CC: cold climates being associated with larger brains and vice versa. Their data are impressive and their conclusion may be, to some degree, correct, but it must be noted that they do not standardize CC for WT, even though they show a very significant overall (between populations) correlation between CC and WT. It is not clear why Beals et al. (1984) did not correct their CC values for weight.

The tripling of CC over the last three million years of human evolution, paralleling an undoubted increase in information-processing ability in this time period (Jerison, 1985, pp. 10–11), clearly justifies our evolutionary interest in relative brain size. It should be noted, however, that in modern humans, most of the variance in mental ability is unrelated to CC. Individual differences in brain size, even when measured accurately by magnetic resonance imaging (e.g., Willerman, Schultz, Rutledge, & Bigler, 1991), appear to account for only about 15% of IQ variance. Obviously, investigation must now focus on neurological variables other than gross brain size if we are to discover the major biological sources of variance in human cognitive abilities. Cortical surface area, for example, may be a better predictor of IQ than brain size (L. Willerman, personal communication, 1992). The recent electrophysiological demonstration of differences in brain cortical connectivity patterns ("circuits") among normal humans performing a task requiring a decision (Gevins et al., 1989) suggests other variables. How *well* a given amount of (normal) cortex functions, meaning, for example, how accurately and how fast local cortical regions do their information processing and different cortical regions communicate among themselves, may be factors more important to intelligence level than brain size *per se*. Already there are experimental approaches to studying this question (e.g., Reed & Jensen, 1993) and it is sure there will be more.

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