

Brain size, IQ, and racial-group differences: Evidence from musculoskeletal traits

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Abstract

A review of the world literature on brain size and IQ by Rushton [Rushton, J. P. (1995). *Race, evolution, and behavior: a life history perspective*. New Brunswick, NJ: Transaction] found that African-descended people (Blacks) average cranial capacities of 1267 cm³, European-descended people (Whites) 1347 cm³, and East Asian-descended people (East Asians) 1364 cm³. These brain size differences, containing millions of brain cells and hundreds of millions of synapses, were hypothesized to underlie the race differences on IQ tests, in which Blacks average an IQ of 85, Whites 100, and East Asians 106. The validity of the race differences in brain size, however, continues to be disputed. In the present study, the race differences in brain size are correlated with 37 musculoskeletal variables shown in standard evolutionary textbooks to change systematically with increments in brain size. The 37 variables include cranial traits (such as jaw size and shape, tooth size and shape, muscle attachment sites, and orbital bone indentations), and postcranial traits (such as pelvic width, thighbone curvature, and knee joint surface area). Across the three populations, the “ecological correlations” [Jensen, A. R. (1998). *The g factor*. Westport, CT: Praeger] between brain size and the 37 morphological traits averaged a remarkable $r = .94$; $\rho = .94$. If the races did not differ in brain size, these correlations could not have been found. It must be concluded that the race differences in average brain size are securely established. As such, brain size-related variables provide the most likely biological mediators of the race differences in intelligence.

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1. Introduction

In the US and around the world, East Asians and their descendants average an IQ of about 106, Europeans and their descendants about 100, and Africans and their descendants about 85. The lowest average IQ scores are reported for sub-Saharan Africa, about 70 (Jensen, 1998; Lynn & Vanhanen, 2002; Rushton, 2000). Average IQ differences between individuals and groups, including mean racial-group differences, show up before age 5, and they last a lifetime (Jensen, 1998).

Among individuals, intelligence is related to brain size. This has been documented in about two dozen studies using magnetic resonance imaging (MRI) to measure brain volume. The overall correlation between IQ and brain size measured by MRI is $>.40$. Gignac, Vernon, and Wickett (in press), Rushton and Ankney (1996), and Vernon, Wickett, Bazana, and Stelmack (2000) have reviewed the evidence. Altogether there are now about 15 studies on over 700 subjects showing that individuals with larger brain volumes have higher IQ scores. This is much higher than the $.20$ correlation found in earlier research using simple head size measures, although even simple head size measures also show the relationship. Rushton and Ankney reviewed 32 studies correlating measures of external head size with IQ scores, or with measures of educational and occupational achievement, and found a mean $r = .20$ ($P < 10^{-10}$) with people of all ages, both sexes, and various ethnic backgrounds.

The races differ in average brain size and this shows up at birth. Rushton (1997) analyzed the enormous US data set known as the Collaborative Perinatal Project. It recorded head circumference measurements and IQ scores from 50,000 children followed from birth to age 7 (Broman, Nichols, Shaugnessy, & Kennedy, 1987). The results showed that at birth, 4 months, 1 year, and 7 years, the East Asian children in the study averaged larger cranial volumes than did the White children, who averaged larger cranial volumes than did the Black children. Within each race, the children with the larger head sizes had the higher IQ scores and by age 7, the East Asian children averaged an IQ of 110, White children an IQ of 102, and Black children an IQ of 90. Moreover, the East Asian children, who averaged the largest craniums, were the shortest in stature and the lightest in weight, whereas the Black children, who averaged the smallest craniums, were the tallest in stature and the heaviest in weight. Therefore, the race differences in brain size were not due to body size.

Studies have also shown that the correlation between brain size and IQ holds true *within* families as well as *between* families (Gignac et al., in press; Jensen, 1994; Jensen & Johnson, 1994; although one study that examined only sisters failed to find the within-family relation; Schoenemann, Budinger, Sarich, & Wang, 2000). The within-family finding is of special interest because it controls for most of the sources of variance that distinguish families such as social class, styles of child rearing, and general nutrition, which differ between families. Jensen and Johnson's study, based on head size measurements of over 7000 sibling pairs, showed the within-family relation for Blacks, as for Whites. When Blacks and Whites were matched for IQ, the Black–White difference in head size disappeared.

Many are surprised to learn that the races differ in brain size (e.g., Brody, in press; Graves, 2002; Kamin & Omari, 1998; Lieberman, 2001) and they question how reliable the evidence

is. In fact dozens of studies from the 1840s to the 1990s, using different methods on different samples, reveal the same strong pattern. Four different methods of measuring brain size—MRI, endocranial volume measured from empty skulls, wet brain weight at autopsy, and external head size measurements—all produce the same results. Using MRI, for example, [Harvey, Persaud, Ron, Baker, and Murray \(1994\)](#) found that 41 Africans and West Indians had a smaller average brain volume than did 67 Caucasians.

Using the method of measuring endocranial volume, the American anthropologist [Samuel George Morton \(1849\)](#) filled over 1000 skulls with packing material and found that Blacks averaged about 5 in.³ less cranial capacity than Whites. These results have stood the test of time ([Gordon, 1934](#); [Simmons, 1942](#); [Todd, 1923](#)). More recently, [Beals, Smith, and Dodd \(1984\)](#) carried out the largest study of race differences in endocranial volume to date, with measurements of up to 20,000 skulls from around the world. Their study found that East Asians, Europeans, and Africans averaged cranial volumes of 1415, 1362, and 1268 cm³, respectively. The skulls from East Asia were 3 in.³ larger than those from Europe, which in turn were 5 in.³ larger than those from Africa.

Using the method of weighing brains at autopsy, the famous French neurologist [Paul Broca \(1873\)](#) found that Whites averaged heavier brains than Blacks with more complex convolutions and larger frontal lobes. (He corroborated the Black–White difference using endocranial volume and also found that East Asians averaged larger cranial capacities than did Whites.) The autopsy results too have stood the test of time. Subsequent studies have found an average Black–White difference of about 100 g ([Bean, 1906](#); [Mall, 1909](#); [Pearl, 1934](#); [Vint, 1934](#)). Some studies have found that the more White admixture (judged independently from skin color), the greater the average brain weight in Blacks ([Bean, 1906](#); [Pearl, 1934](#)). More recently, [Ho, Roessmann, Straumfjord, and Monroe \(1980\)](#) found in an autopsy study of 1261 American adults, that 811 White Americans averaged 1323 g and 450 Black Americans averaged 1223 g—a difference of 100 g. Since the Blacks and Whites in the study were similar in body size, differences in body size cannot explain away the differences in brain weight.

A final way of estimating brain size is by cranial volume calculated from external head size measurements (length, width, height). The results again confirm the racial differences. [Rushton \(1991, 1992, 1993, 1994\)](#) and [Rushton and Osborne \(1995\)](#) carried out a series of studies estimating brain size this way from five large archival data sets. In the first of these studies, [Rushton \(1991\)](#) examined head size measures in 24 international military samples collated by the U.S. National Aeronautics and Space Administration and after adjusting for the effects of body height, weight, and surface area, found that the cranial capacity for East Asians was 1460 and for Europeans it was 1446 cm³. In the most comprehensive of these studies, [Rushton \(1992\)](#) calculated average cranial capacities for East Asians, Whites, and Blacks from a stratified random sample of over 6000 U.S. Army personnel. The East Asians, Whites, and Blacks averaged 1416, 1380, and 1359 cm³, respectively. The East Asians averaged 36 cm³ more capacity than did the Whites, and the Whites averaged 21 cm³ more capacity than did the Blacks. This study allowed precise adjustments for all kinds of body size measures. Yet adjusting for these, or other variables, did not erase the average racial differences in cranial capacity.

Are these findings attributable simply to race differences in body size? The world database from: (a) autopsies, (b) endocranial volume, (c) head measurements, and (d) head measurements corrected for body size was summarized by Rushton (1995, pp. 126–132, Table 6.6). The results in cubic centimeters or equivalents were: East Asians = 1351, 1415, 1335, 1356 (mean = 1364); Whites = 1356, 1362, 1341, 1329 (mean = 1347); and Blacks = 1223, 1268, 1284, and 1294 (mean = 1267). The review found the overall mean for Asians to be 17 cm³ more than that for Europeans and 97 cm³ more than that for Africans. Within-race differences, due to the method of estimation, averaged 31 cm³. Since 1 in.³ of brain matter contains millions of brain cells and hundreds of millions of synapses or neural connections, Rushton hypothesized that these brain size differences help to explain why the races differ in average IQ. Similarly, Jensen (1998, p. 443) calculated an “ecological correlation” of .998 between brain size and IQ across the three races.

It is important to note, for the historical record, that by 1871, Charles Darwin considered the race differences in brain size so well established that he relied on them as evidence in favor of his then controversial theory of human origins. Even Franz Boas (1894), who is sometimes described as the “true” founder of American anthropology for being the first to challenge “Eurocentric racism,” initially accepted that the races differed in brain size and drew important conclusions about relative intellectual performance based on the amount of overlap in the distributions. Boas analyzed data from Topinard (1890) and found that only 27% of Blacks exceeded the White brain size average, rather than the 50% that should have done had the races been equal. Arguing that “the greater the central nervous system, the higher the faculty of the race and the greater its aptitude to mental development,” Boas concluded: “We might, therefore, anticipate a lack of men of high genius (among Blacks).”

Such conclusions were widely shared among scientists up until the 1930s. Darwin’s cousin, Sir Francis Galton (1869), began a scientific research program on intelligence that continues to this day. Galton (1888) examined the relation between brain size and cognitive ability by multiplying head length by breadth by height in 1095 university students, plotting the results against class rank, and calculating that those who obtained high honors had a brain size 2–5% greater than those who did not. As described, modern studies have corroborated Galton’s results (Rushton & Ankney, 1996; Vernon et al., 2000).

Despite 150 years of evidence that the races differ in brain size, and that brain size is related to intelligence, this research is often claimed to be inconclusive or to reflect little more than personal bias (Brody, *in press*; Gould, 1996; Graves, 2002; Kamin & Omari, 1998; Lieberman, 2001). The change in view from Darwin’s time to today did not occur because of more and better data or methods of analysis, but because of changes in the political climate. This began when Franz Boas (1938) and his students chipped away at traditional “hierarchical” thinking throughout the 1920s and 1930s, rejecting an evolutionary explanation of IQ and instead championing the omnipotence of culture. Subsequent political events such as World War II and the reactions to the Holocaust, the U.S. Civil Rights Movement, and the struggle for the hearts and minds of the Third World during the Cold War, resulted in a success for Boas’ mission to decouple biology from culture (Degler, 1991; Miele, 2001). For many years, empirical research on race differences in brain size and intelligence virtually

ceased, with the literature dominated by vigorous critiques, notably from Gould (1981, 1996), Kamin (1974), and Tobias (1970).

Critiques of the race/brain size/IQ relationship continue to be forthcoming, including of the most recent literature (e.g., Brody, *in press*; Graves, 2002; Kamin & Omari, 1998; Lieberman, 2001). The main analytical arguments offered against accepting race differences in brain size at face value include alleged inadequacies in the control of variables such as body size, social class, and nutritional status; the unrepresentativeness of the samples; artifacts of data preparation, including personal bias; computational errors; weak effect sizes and their possible interactions with other variables; and the overgeneralization of conclusions. Although many of these criticisms have been tested, refuted, and replied to, and serious errors of omission and commission found in the critiques (e.g., Rushton, 2001; Rushton & Ankney, 2000), the belief remains widespread that the races do not differ reliably in brain size.

The present study aims to reduce substantially the uncertainty about race differences in brain size by analyzing data used by forensic anthropologists to identify race, age, and sex from the bones of skeletons (Byers, 2002). A broad-based extension and conceptual replication, such as the one provided here, will extend the parameters of the debate which has to take the totality of the evidence into account. The data and analyses presented here are not as susceptible to such ad hoc explanations as “unrepresentative samples” and “lack of controls for social class and nutrition,” for these are not known to affect the variables under discussion in any major way. Indeed, some of the musculoskeletal traits considered here (e.g., jaw size) are more widely identified with racial characteristics than is brain size, although their association with brain size has been much less widely known.

2. Method

In the present study, the race differences in brain size are correlated with race differences in 37 musculoskeletal traits identified in standard evolutionary anatomy textbooks as being systematically related to brain size increments over the hominoid line (Aiello & Dean, 1990; Conroy, 1997; Fleagle, 1999). The data on the racial attributes are taken from standard forensic anthropology textbooks (Binkley, 1989; Brues, 1990; Byers, 2002; Krogman & Iscan, 1986; Reichs, 1998). Whenever a different reference is used to fill-in a missing data point, this is identified. Traits were chosen to sample as much of the skeleton as possible and were included only when data were available for at least two of the three racial groups.

The three populations under consideration have mean absolute cranial capacities of African Americans (1356 cm³), European Americans (1371 cm³), and East Asian Americans (1383 cm³). These cranial sizes are taken from the stratified random sample of over 6000 U.S. Army personnel studied by Rushton (1992) prior to corrections made for body size, sex, and military rank. However, similar proportionate differences are also found even after the military data are corrected for stature and weight (*viz.*, 1359, 1380, 1416 cm³, respectively). They are also found for the world averages calculated by Rushton (1995) from a review of over 150 years of research (*viz.*, 1267, 1347, and 1364 cm³, respectively). Because the

Table 1
Rank order of size and shape across the three races on 41 morphological traits

Trait number and name	Africans	Europeans	East Asians
1. Cranial capacity (cm ³)	1356 (1)	1371 (2)	1383 (3)
2. Height (cm)	169.5 (2)	170.5 (1)	166.3 (3)
3. Weight (kg)	70.7 (2)	71.0 (1)	69.5 (3)
4. EQ	6.38 (1)	6.50 (2)	6.95 (3)
<i>A. Cranial traits (11)</i>			
5. Cranial shape	Narrowest (1)	Broader than Africans (2)	Broadest (3)
6. Cranial length	Longest (1)	Shorter than Africans and longer than Asians (2)	Shortest (3)
7. Sagittal outline	Lowest vault, depressed postbregma (1)	Higher than Africans, lower than Asians (2)	Highest (3)
8. Nasal bone prominence	Slight prominence (1.5)	Most prominent (3)	Slight prominence (1.5)
9. Facial prognathicism	Most (1)	Middle (2)	Least (3)
10. Bizygomatic breadth (reverse keyed)	Widest (1)	Intermediate width (2)	Narrowest (3)
11. Palatal form	Least parabolic (1)	Parabolic/elliptic (2)	Widest parabolic (3)
12. Supraorbital ridge shape (reverse keyed)	Large, table-like with glabellar depression (1)	Small, smooth, and arched (2)	Arched and smallest (3)
13. Mastoid process (reverse keyed)	Largest, two heads (1)	Small and pointy (2)	Smallest and stubby (3)
14. Neurocranium position	Lowest (1)	Over top of face (2)	Most over the top of face (3)
15. Postorbital constriction size	Largest (1)	Larger than Africans, smaller than Asians (2)	Smallest (3)
<i>B. Teeth and mandible traits (8)</i>			
16. Incisor shape	Rarely shoveled (1)	Sometimes shoveled (2)	Frequently shoveled (3)
17. Number of teeth	32 (1)	30–32 (2)	28–32 (3)
18. Size of molars	Largest (1)	Smaller than Africans (2)	Smallest (3)
19. Orthognathism of mandible	Longest and lowest (1)	Medium length and height (2)	Short and high (orthognathic) (3)
20. Shape of mandible	Least V-shaped (1)	Less V-shaped than Asians (2)	Most V-shaped (3)
21. Width of mandibular condyles	Closest together (1)	Wider apart than Africans closer than Asians (2)	Widest apart (3)
22. Chin prominence	Reduced (1)	Prominent (3)	Moderate (2)
23. Length of tooth roots (reverse keyed)	Long (1)	Short (2.5)	Short (2.5)
<i>C. Neck traits (3)</i>			
24. Neck shape	Broad and strait (1)	Narrow, curved, and long (2)	–
25. Mass of nuchal muscles (reverse keyed)	Large (1)	Medium (2)	Small (3)

(continued on next page)

Table 1 (continued)

Trait number and name	Africans	Europeans	East Asians
26. Size of nuchal crest and bony markings	Some pronounced markings (1)	Smoother to absent (2)	Absent (3)
<i>D. Pelvic traits (3)</i>			
27. Size of transverse diameter (mm)	122 (1)	132 (2)	–
28. Size of anteroposterior diameter (mm)	103 (1)	118 (2)	–
29. Bi-iliac width (mm)	250 (1)	270 (3)	252 (2)
<i>E. Lower limb traits (12)</i>			
30. Femoral head size	Smallest (1)	Intermediate between Africans and Asians (2)	Largest (3)
31. Femoral condylar lateral profile	Most circular ^a (1)	Elliptical ^a (2)	Oval ^a (3)
32. Femoral bicondylar width (mm)	79.50 ^a (1)	83.05 ^a (2)	–
33. Femoral pilaster	Small pilaster ^b (1)	Large pilaster ^b (2)	Largest pilaster ^b (3)
34. Femoral shaft curvature index	76.6 ^b (1)	97.0 ^b (2)	102.2 ^b (3)
35. Size of tibial plateau	Smallest ^a (1)	Intermediate ^a (2)	Largest ^a (3)
36. Tibial plateau flatness	Curved (1)	Flat (2.5)	Flat (2.5)
37. Lateral tibial condyle concaveness	Flat (1)	Varies (2)	Concave (3)
38. Tibial plateau angle (reverse keyed)	High (1)	Low (2)	–
39. Tibial condyle size	Smallest (1)	Larger than Africans (2)	Largest (3)
40. Size of distal tibial head	47.07 ^a (1)	53.23 ^a (2)	–
41. Tibial anterior border sharpness	Rounded (1)	Sharp (2.5)	Sharp (2.5)

Dashes indicate missing data.

^a Craig (1995, pp. 777–780).

^b Steele and Bramblett (1988, p. 59).

forensic skeletal data are almost entirely from the US, the uncorrected military data were selected as providing the best comparisons.

There is disagreement about whether and how brain size should be corrected for body size when examining brain size relations. Controlling for body size, however, changes the question from “Is absolute brain size correlated with variable X ?” to “Is relative brain size correlated with variable X ?” Typically, controlling for body size has little effect on the final results. For example, although whether absolute and relative brain sizes are related to IQ are different questions, Rushton and Ankney’s (1996) review of the evidence showed that the answers to both are “yes.”

Although analysis of covariance is typically used to control for the small differences found among humans, it is to some degree an overcorrection, because head size itself is part of stature and body weight. Regardless, in the present study, it is inapplicable for the three, mainly rank-ordered, data sets. Although there is no real theoretical justification for controlling for body size in this study, nonetheless, a correction is made for it based on Jerison's (1973, 2000) encephalization quotient (EQ), which is used in zoological studies, and occasionally in the human literature, too (e.g., Rushton, 1991). The EQ provides an index of "excess" brain tissue for various species based on their deviation from the regression of brain weight on body weight and allows brain size comparisons across diverse animal species based on a single brain-to-body-size-ratio. The average EQ is defined as 1.0. Monkeys and apes have large brains relative to their body size (EQs = 1.0 to 5.0). Human EQs are over 6, which is about three times larger than would be expected for a typical primate of our body size. Although alternative exponents have been debated, the most widely used equation is:

$$\text{EQ} = \text{cranial capacity (cm}^3\text{)} / (0.12) (\text{body weight in grams})^{0.67}$$

In his most recent statement on the evolution of human intelligence, Jerison (2000) explicitly accepted both the validity of the MRI brain volume/IQ correlation among humans, and of the race differences in brain size. He further stated that what applies between-species should also apply within-species. A previous study (Rushton, 1991) calculated EQs for East Asian and European military samples (EQs = 7.26 vs. 6.76, respectively, $P < 0.05$), whose cranial capacities, corrected for body size, were 1460 and 1446 cm³.

Table 1 gives a brief description of 41 morphological traits and the rank order for each of the three population groups based on an "average" individual (e.g., collapsed across sex). It begins with absolute brain size (Trait 1), then stature (Trait 2), body weight (Trait 3), and relative brain size based on Jerison's EQ (Trait 4), after which it is divided into five sections dealing with 37 musculoskeletal traits. Section A reports data on 11 cranial traits (5–15), Section B on 8 teeth and mandibular traits (16–23), Section C on 3 neck traits (24–26), Section D on 3 pelvic traits (27–29), and Section E on 12 lower limb traits (30–41). Tied ranks are assigned the average of the ranks that they would have received without ties. Missing data are shown as dashes. To test the hypothesis that both absolute and relative brain size (Traits 1 and 4) are associated with the size and shape of the 37 musculoskeletal traits, both Pearson product-moment (r) and Spearman rank-order (ρ) correlations are calculated.

3. Results

There were missing data for 6/111 (5%) of the categories, all involving East Asians, and ties on 4 of the 105 remaining ones (4%). The first set of correlations was calculated using a pairwise deletion method to handle missing data, thereby retaining as many traits as possible for analysis (all 37 traits). Absolute and relative brain size (Traits 1 and 4) intercorrelated 1.00, and both correlated with a mean r of .94 (median = 1.00) across the 37 traits. They showed similar high correlations across the separate trait categories, viz., on 11 cranial traits

(5–15), mean $r = .91$; on 8 teeth and mandibular traits (16–23), mean $r = .92$; on 3 neck traits (24–26), mean $r = 1.00$; on 3 pelvic traits (27–29), mean $r = .83$; and on 12 lower limb traits (30–41), mean $r = .98$.

Virtually identical results occurred using a listwise deletion method, where only complete data were available (31 traits). Brain size correlated with the 31 traits that remained with mean Pearson and Spearman correlations of .96 (median = 1.00). Six traits lacked data on East Asians (24, 27, 28, 32, 38, and 40), five traits had either ties or reversals that involved East Asians and Whites (Traits 22, 23, 29, 36, and 41), and one had a tie and reversal that involved Blacks (Trait 8). Out of the 31 traits on which full data were available, 25 gave a perfect three-way ranking. The probability of getting this three-way ranking once in a row is $3!$ or 1 in 6; to get it 25/31 times has an associated binomial probability of less than 10^{-10} . Finally, to “gild the lily,” we calculated Kendall’s Coefficient of Concordance and found $W = 0.75$, which also has an associated probability of $P < 0.001$.

4. Discussion

As brain size increases from 1356 to 1383 cm³ across the three racial groups, 37 musculoskeletal traits vary accordingly with a remarkable mean $r = .94$, $\rho = .94$. These changes occurred on both cranial traits (temporalis fossae, postorbital constrictions, mandibles, dentition, neck muscle attachments), and postcranial traits (pelvic widths, femoral heads, tibial plateaus). Because the physical traits are not completely independent of each other, with some being logically as well as adaptively related, there were not, in fact, 37 independent test trials of the hypothesis. Nonetheless, it is noteworthy that the correlations with racial differences in brain size are as high for the 12 lower limb traits (Traits 30–41; $r = .98$) as they are for the 11 cranial traits (Traits 5–15, $r = .91$).

It is widely accepted that during hominoid evolution, the expansion of the brain had cascading effects on the musculoskeletal system (Aiello & Dean, 1990; Conroy, 1997; Fleagle, 1999). It is of great interest to see these relationships continue within the much smaller variance presented by the three major human races. This shows the results are highly robust.

It could be argued that the race differences in these musculoskeletal traits are only adventitiously correlated with the brain size differences (in the same way as would be skin color and hair texture), and that no causal connection exists. Hence, in what follows, we illustrate how increasing brain size is causally related to the skeletal traits (following Aiello & Dean, 1990; Conroy, 1997; Fleagle, 1999).

Fig. 1 shows that as brain size expanded during human evolution, it was accompanied by broader, shorter, increasingly spherically shaped heads, with less keeling or sagittal outline (Cranial Traits 5–7). These relations were confirmed by Rushton and Ankney (2000) in a canonical discriminant analysis of the same U.S. Army data that provided the cranial capacity, height, and weight data (Traits 1–3) for the present study. East Asians had significantly greater head breadth and head height, relative to head length, than did Whites, who had relatively greater head breadth and head height than did Blacks. Moreover, as brain tissue in the frontal lobes expanded, it took up the space previously occupied by bony supraorbital

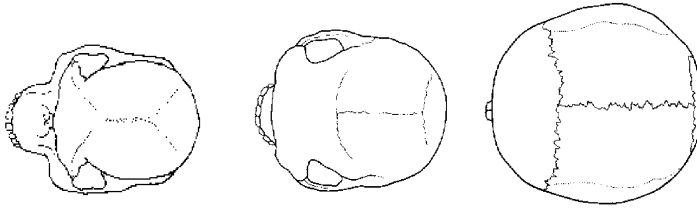


Fig. 1. With increasing brain size, skulls became more spherical in shape and expanded over the top of the face. East Asians average wider and more spherically shaped skulls than do Whites, who average wider and more spherically shaped skulls than do Blacks.

rims, thereby causing a decrease in glabellas (Cranial Trait 12). Thus, predictably, East Asians and Whites have less pronounced glabellas than do Blacks.

Fig. 2 illustrates that as brain tissue expanded to make the more spherically shaped head illustrated above, it increased the smoothness of the skull. Consequently, there were fewer and smaller attachment sites, such as the decrease in the mastoid process that is used to attach jaw muscles (Cranial Trait 13). East Asians average a smoother skull with a smaller mastoid process than do Whites, who average a smoother skull with a smaller mastoid process than do Blacks.

Fig. 3 illustrates that as brain tissue expanded, it did so by filling in the temporal fossa, an opening in each zygomatic arch, and the postorbital constriction, an indentation of the skull behind the eye sockets (Cranial Trait 15). This required a reduction in the large jaw-closing muscles (the temporalis and masseter muscles) that run through the temporal fossa and the postorbital constriction and attach to the jaw, and serve to close the jaw. East Asians have less postorbital constriction and smaller temporal fossae than do Whites who have less postorbital constriction and smaller temporal fossae than do Blacks.

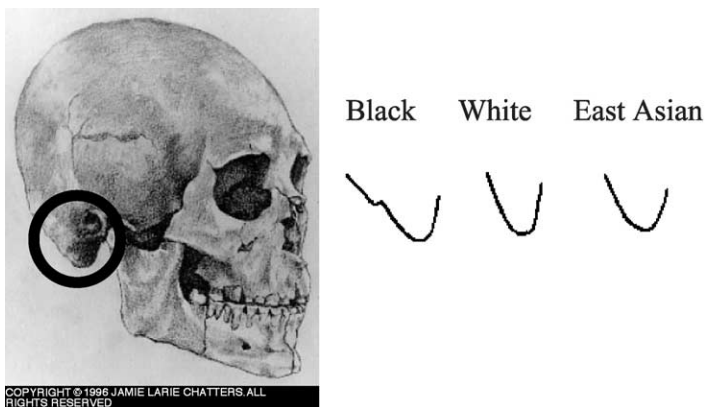


Fig. 2. With increasing brain size there is increased smoothness of the skull with fewer and smaller muscle attachment sites, such as the decrease in the mastoid process that is used to attach jaw muscles. East Asians average a smoother skull with a smaller mastoid process (circled) than do Whites, who average a smoother skull with a smaller mastoid process than do Blacks.

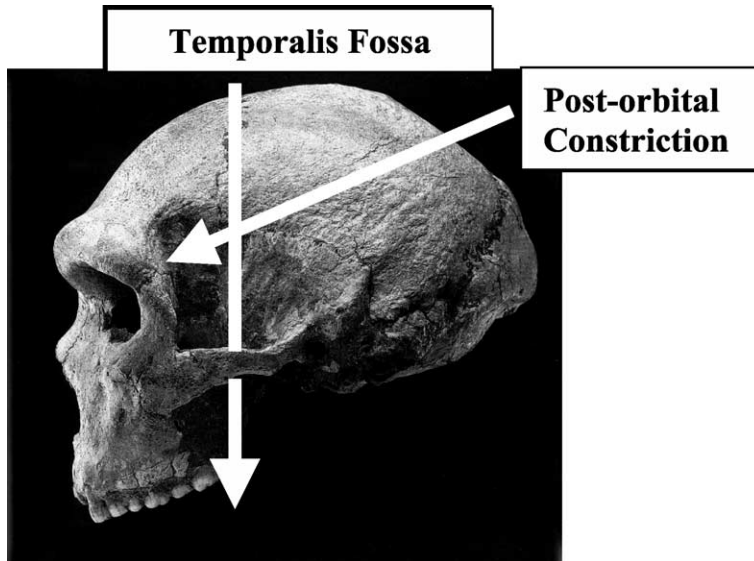


Fig. 3. With increasing brain size there are decreases in the postorbital constriction and temporalis fossae, which are indentations to allow the temporalis and masseter muscles, the large jaw-closing muscles, to run through and close the heavy jaw. East Asians average less postorbital constriction than do Whites, who average less postorbital constriction than do Blacks.

Fig. 4 illustrates that with increasing brain size there is decreasing prognathism and a flatter face (Cranial and Mandibular Traits 9, 11, 19). Muscles are no longer available to hold up a heavy forward jutting jaw. Since smaller temporalis muscles cannot close as large a jaw, jaw size was reduced. East Asians average a flatter face than do Whites, who average a flatter face than do Blacks. Consequently, there is less room for teeth, resulting in smaller teeth, shorter roots, and fewer teeth (Mandibular Traits 16–18, 23). The decrease in jaw size (orthognathism replacing prognathism) in turn led to decreased size of neck muscles and the bony protuberances to which they attach (nuchal crests, cervical spinous process), that are



Fig. 4. With increasing brain size there is decreased prognathism and a flatter face. Muscles are no longer available to hold up a heavy forward jutting jaw. East Asians average a flatter face than do Whites, who average a flatter face than do Blacks.

no longer required for supporting heavy prognathic faces (Neck Traits 25–26). East Asians and Whites average smaller jaws, fewer and smaller teeth, and shorter roots than do Blacks and have reduced neck muscles and smaller spinous processes and less prognathic faces than do Blacks.

Fig. 5 illustrates that widening brain cases led to widening bichondylar breadths of the mandible, i.e., the distance between the two surfaces at the back of the jaw that attach to the base of the cranium (Mandibular Traits 20–21). In East Asians this is wide, in Blacks it is narrow, and Whites are in between. [Stringer, Dean, and Humphreys \(1999\)](#) confirmed many racial differences in jaws and teeth, including the bichondylar breadth.

Fig. 6 illustrates that with increasing brain size, the pelvis broadens to provide a wider birth canal to allow the birth of larger-brained offspring (Pelvic Traits 27–29). East Asian and White women average wider birth canals than do Black women.

Fig. 7 illustrates the curvature of the femur or thighbone (leg trait 34). With a widening pelvis, the thighbone exits the pelvis at a wider angle and so has to curve back inwards to make contact with the weight bearing knee, near the center of gravity. East Asians average greater femoral curvature than do Whites, who average greater femoral curvature than do Blacks. The curving of the femur, in turn, led to the formation of the linea aspera (Leg Trait 33), which is a pilaster (ridge) that prevents the bone from breaking due to bending stresses, and on which the races also differ in the predicted direction.

Fig. 8 illustrates a bell curve for the upper part of the knee joint (Leg traits 30, 31). The femoral condyles increased in size and flatness to produce a more stable platform for more curved thighbones. Consequently, too, the tibial plateau increased in size and concavity to form a more stable joint (Leg Traits 35–37, 39). East Asians average a wider knee joint angle than do Whites, who average a wider knee joint angle than do Blacks.



Fig. 5. With increasing brain size, there is increased bichondylar breadth of the mandible, a widening of the upper back-of-the-jaw, which provides its attachment to the cranium. East Asians (left) average a wider upper back-of-the-jaw than do Whites (right), who average a wider upper back-of-the-jaw than do Blacks (not shown). A similar pattern is observed for the lower jaw.

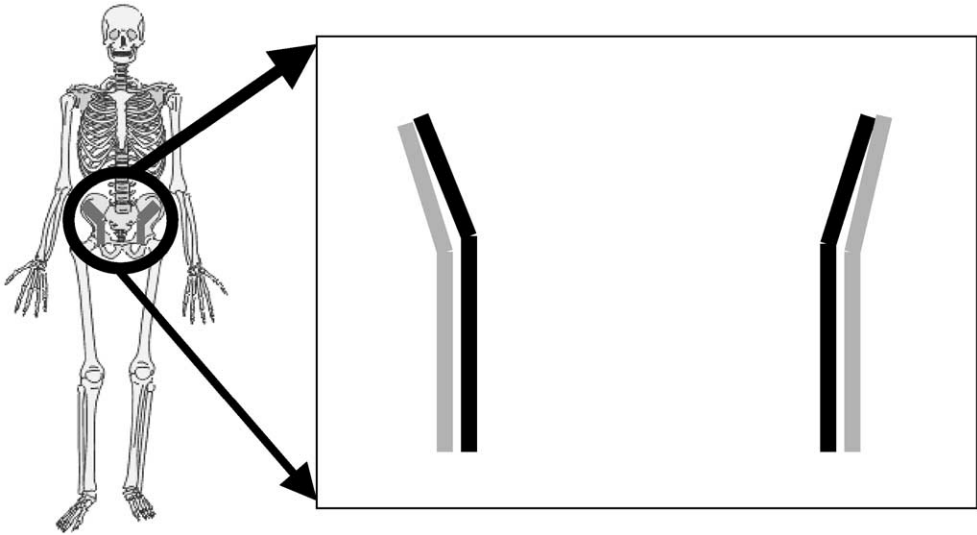


Fig. 6. With increasing brain size, the pelvis widens to allow the birth of larger-brained offspring. White women (gray line) average a birth canal of 27.4 cm wide and Black women (black line) average a birth canal of 24.6 cm wide.

Over evolutionary time, increasing brain size also affected traits other than those in the musculoskeletal system. These include life-history traits and the complexity of behavior. For example, because it requires a longer time to grow a bigger brain, there is a consequent delay in rate of maturation. Thus, [Smith \(1989\)](#) found that brain size correlated greater than .80 across 21 primate species with length of gestation, age of weaning, age of eruption of first

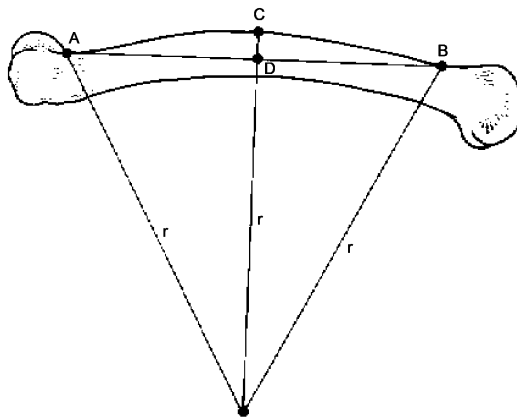


Fig. 7. The calculation of femoral (thighbone) curvature (after [Aiello & Dean, 1990](#)). With a widening pelvis, the thighbone exits the pelvis at a wider angle and so has to curve back inwards to make contact with the weight-bearing knee. East Asians average a more curved thighbone than do Whites, who average a more curved thighbone than do Blacks.

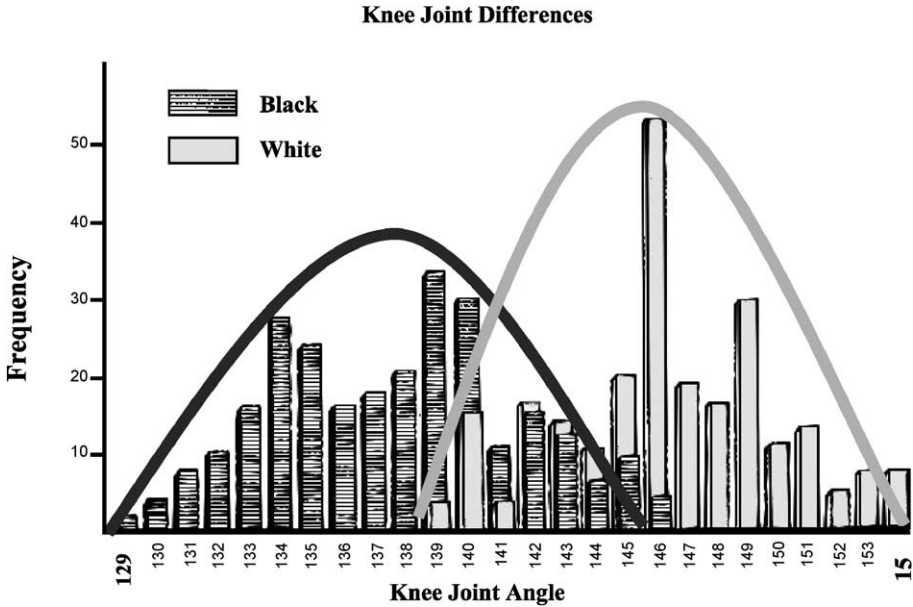


Fig. 8. The bell curve for knee joints. East Asians average a wider knee joint angle than do Whites, who average a wider knee joint angle than do Blacks, in order to provide a more stable platform for the more curved thighbones from wider pelves.

molar, body weight, interbirth interval, sexual maturity, and life span. Many of these life-history correlates are also found among the human races (Rushton, 1995, 2000). For example, larger brained populations such as East Asians and Whites, whether tested in their home continents or in North America, give birth at later mean gestational ages than do Blacks, and their children subsequently develop more slowly in bone ossification (measured by X-rays) and dental development, and they reach puberty later and they live longer (Eveleth & Tanner, 1990).

In conclusion, brain size is at the center of a nexus of covarying evolutionary attributes, including intelligence. The finding that changes in musculoskeletal traits correlate with the already documented life-history traits provides corroboration for the validity of the observed racial-group differences in brain size. The mean correlation of $r = .94$ between brain size and the 37 skeletal traits across the three racial groups could not have occurred if brain size did not vary systematically across the races in the predicted manner.

The main unanswered question at this point has to do with why brain size is correlated with intelligence. While the answer seems simple, that people with bigger brains think better, the correlation is low enough to suggest that size is only one among other contributing factors: Is it the number of neurons, or amount of myelin, glial cells, etc. Several studies supporting a brain size/efficiency model were reviewed in Gignac et al. (in press). For example, Haier et al. (1995) used MRI to measure brain volume and glucose metabolic rate (GMR) to measure glucose uptake (an indicator of energy use). They found a correlation of $-.58$ between GMR

and IQ, showing that more intelligent individuals have more efficient brains because they use less energy in performing a given cognitive task. In any individual, however, energy use increases with the increasing complexity of the cognitive task. Perhaps it is in this realm of brain function, rather than in further studies of size per se, that the next important advance on this topic will be made.

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