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Anthropometric Comparison of Mentally Retarded Males With and Without the Fragile X Syndrome

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Abstract

An anthropometric survey of 41 variables (weight, height, 10 linear, 4 breadth, 22 craniofacial, 2 skinfold, and testicular volume), including multivariate discriminant analysis, was undertaken on 110 mentally retarded males (39 with and 71 without the fra(X) syndrome). The mean Z scores of the fra(X) syndrome males fell between -2.00 and 8.38 for bizygomatic diameter and testicular volume, respectively, and the range of the mean Z scores of the non-fra(X) males was from -2.64 to 2.26 for hand breadth and testicular volume, respectively. There was a statistically significant difference ($P < .05$) between fra(X) and non-fra(X) males for 18 measurements (weight, height, 7 linear, 2 breadth, 5 craniofacial, 1 skinfold, and testicular volume), with the greater measurements (excluding bizygomatic diameter) found in fra(X) males. Sitting height, knee-buttock length, middle finger length, and hand length were negatively correlated ($P < .05$) with age, whereas bizygomatic diameter, ear length, and ear width were positively correlated ($P < .05$) with age and head circumference, head length, and outer canthal distance were positively correlated ($P < .05$) with fra(X) chromosome expression in the fra(X) males. Triceps and subscapular skinfold thicknesses were negatively correlated ($P < .05$) with age, whereas ankle breadth, ear length, ear width, and nose length were positively correlated ($P < .05$) in the non-fra(X) males. Discriminant analysis of 34 fra(X) and 71 non-fra(X) males resulted in a discriminant function based on 6 of 17 anthropometric variables and age. In the discriminant analysis, patients with the fra(X) syndrome were distinguished from mentally retarded males without the fra(X) syndrome at an overall correct classification rate of 97.1% in our sample. The 6 anthropometric variables in the discriminant function were the Z scores representing testicular volume, ear width, head breadth, bizygomatic diameter, hand breadth, and hand length. Additional research is needed to test the usefulness of these variables in screening mentally retarded males for the fra(X) syndrome.

Keywords

anthropometric variables; correlations; discriminant analysis; Martin-Bell syndrome; X-linked mental retardation

INTRODUCTION

After Down syndrome, the fragile X [fra(X)] or Martin-Bell syndrome is the most common genetic cause of mental retardation. This syndrome usually affects males (although females can also be affected) and is characterized by mental retardation, large ears, an elongated face, macroorchidism, and mild connective tissue dysplasia [Hagerman, 1987]. Published surveys indicate that 1.6–6.2% of institutionalized males [Sutherland, 1982; Froster-Iskenius et al., 1983], about 5% of mildly retarded school children [Kähkönen et al., 1986], and 5.3–15.7% of apparently autistic individuals [Watson et al., 1984; Blomquist et al., 1985] have the fra(X) syndrome. Few anthropometric studies of mentally retarded males with and without the fra(X) syndrome have been done, especially with multivariate analysis [Partington, 1984; Meryash et al., 1984; Loesch et al., 1988; Butler et al., 1988a, b]. Through anthropometric studies with multivariate analysis, physical and clinical characteristics should be identified that may be useful for selecting individuals for fra(X) chromosome studies. To our knowledge, we report the first multivariate discriminate analysis of anthropometric variables of only mentally retarded males with and without the fra(X) syndrome in order to identify variables useful for screening persons with mental retardation for this syndrome.

MATERIALS AND METHODS

Patients

We studied 71 white fra(X)-negative mentally retarded males with no recognizable cause of their mental retardation. Their estimated average IQ was 20, with an average age of 34.0 years (range of 3.8–71.6 years). Thirty-nine (34 white and 5 black) fra(X)-positive mentally retarded males (estimated average IQ of 40; average age of 27.2 years with a range of 2.5–75.6 years; and average fra(X) expression of 26% with a range of 3–58%) were included in this anthropometric study. The 71 fra(X)-negative males were from 70 families, and the 39 fra(X)-positive males were from 30 families.

Anthropometric Measurements

Physical examinations and anthropometric measurements were made by one of the authors (M.G.B., M.S.W., or W.R.B.) according to standard techniques as presented by Weiner and Lourie [1969] and Farkas [1981]. The anthropometric variables consisted of the following: weight, height, sitting height, arm span, upper body/lower body segment ratio, total hand length, middle finger length, palm length, hand breadth, maximum fist breadth (thumb knuckle-knuckle), wrist breadth, ankle breadth, total foot length, head circumference, head length, head breadth, cephalic index, minimal frontal diameter, nose breadth, nose length, inner canthal distance, outer canthal distance, lower face height (gnathion-nasion), face height (gnathion-trichion), bizygomatic diameter, bigonial diameter, auricular head height

(vertex-porion), upper head height (vertex-nasion), head height (vertex-gnathion), supraorbital diameter (frontosupraorbitale-frontosupraorbitale), mandibular arc (tragion-gnathion-tragion), depth of lower third of face (tragion-gnathion), philtrum length, ear length, ear width, shoulder-elbow length, elbow-fingertip length, knee-buttock length, testicular volume, and triceps and subscapular skinfolds. Skinfold measurements were recorded to the nearest 0.5 mm with a Lange skinfold caliper. Arm span and head circumference were recorded to the nearest mm with a steel tape. Weight was measured with a balanced-beam scale, height and linear values were measured with an anthropometer or sliding calipers, breadth measurements were obtained with a spreading caliper, and testicular volume was estimated by the use of a Prader orchidometer (if greater than 25 mL the length and width were measured with a sliding caliper, and volume was calculated by the use of the equation $\pi/6 \times L \times W^2$).

Statistical Analysis

Z scores were computed using normative measurements to control for age, sex, and race effects. Z scores were calculated from the following formula: $Z = (X - \bar{X})/SD$, where SD is standard deviation of the normal control individual, $\bar{X}$ is the mean of the normal control individual, and X is the measurement of the subject. Normative values were obtained from published sources [Herskovits, 1930; Krogman, 1970; National Center for Health Statistics, 1970, 1972, 1974a,b, 1979, 1987, Hajnis, 1974; Feingold and Bossert, 1974; Tanner and Whitehouse, 1975; Piedade et al., 1977; Snyder et al., 1977; U.S. Army, 1980; Farkas, 1981; Malina and Roche, 1983; Roche and Malina, 1983a,b].

T Tests were undertaken on the Z score data to determine if significant anthropometric differences exist between fra(X) and non-fra(X) males. Correlation analysis was also undertaken on the anthropometric variables versus fra(X) chromosome expression and age for the fra(X) males and the variables versus age for the non-fra(X) males.

A forward stepwise method of discriminant analysis [Enslein et al., 1977] was performed on 30 of the anthropometric Z score variables and age of individuals from 2 groups of mentally retarded males: 13 white patients with the fra(X) syndrome and 50 white males without the fra(X) syndrome. To test the accuracy of discrimination based on the analysis of 13 fra(X) and 50 non-fra(X) males, a second group of 21 white fra(X) and 21 non-fra(X) syndrome males was studied with discriminant analysis. Subsequently, a third discriminant analysis was performed on 17 of the anthropometric variables from a combined total of 34 white fra(X) syndrome patients and 71 white males without the fra(X) syndrome.

RESULTS

Figure 1 shows the average Z score data represented by bar graphs of the 41 anthropometric variables on all fra(X) and non-fra(X) males. Table I shows numerical Z score data for the variables on all mentally retarded males with and without the fra(X) syndrome. The mean Z scores of the fra(X) syndrome males fell between -2.00 and 8.38 for bizygomatic diameter and testicular volume, respectively. On the mentally retarded males without fra(X) syndrome, the mean Z scores fell between -2.64 and 2.26 for hand breadth and testicular volume, respectively. Abnormal anthropometric variables (-2 or $+2$ SD) in fra(X) males

were testicular volume (mean Z score of 8.38), ear width (3.19), ear length (2.54), and bizygomatic diameter (−2.00). In the mentally retarded males without the fra(X) syndrome, hand breadth (mean Z score of −2.64), sitting height (−2.07), and testicular volume (2.26) were abnormal.

Significant differences ($P < .05$) were found between fra(X) and non-fra(X) males with respect to 18 measurements (weight, height, 7 linear, 2 breadth, 5 craniofacial, subscapular skinfold, and testicular volume), with the greater measurements (excluding bizygomatic diameter) found in the fra(X) males (Table I). Sitting height, knee-buttock length, middle finger length, and hand length were negatively correlated ($P < .05$) with age, whereas bizygomatic diameter, ear length, and ear width were positively correlated ($P < .05$) with age, and head circumference, head length, and outer canthal distance were positively correlated ($P < .05$) with fra(X) chromosome expression in the fra(X) males. Triceps and subscapular skinfold thicknesses were negatively correlated ($P < .05$) with age, whereas ankle breadth, ear length, ear width, and nose length were positively correlated in the non-fra(X) males (Table II).

Discriminant analysis of the 13 white fra(X) and 50 white non-fra(X) males resulted in a discriminant function based on 4 of the 30 anthropometric variables and age. In the discriminant analysis, patients with the fra(X) syndrome were distinguished from mentally retarded males without the fra(X) syndrome at an overall correct classification rate of 95.2% in this sample (Fig. 2). The 4 anthropometric variables in the discriminant function were the Z scores representing testicular volume, ear width, bizygomatic diameter, and head breadth. With the use of these 4 anthropometric variables, the accuracy of discrimination was 95.2% in a test sample of 21 white fra(X) males and 90.5% for a second test sample of 21 white non-fra(X) males (Fig. 2). A final discriminant analysis was performed on the combined group of 34 white fra(X) and 71 non-fra(X) males, which resulted in a discriminant function based on 6 of 17 anthropometric variables and age. In this discriminant analysis, patients with the fra(X) syndrome were distinguished from mentally retarded males without the fra(X) syndrome at an overall correct classification rate of 97.1% in this sample (Fig. 3). The 6 anthropometric variables in this discriminant function were the Z scores representing testicular volume, ear width, bizygomatic diameter, head breadth, hand breadth, and hand length.

DISCUSSION

Several manifestations, such as an elongated face, large ears, and macroorchidism, are recognized characteristics of individuals with the fra(X) or Martin-Bell syndrome. Our analysis of mentally retarded males with and without the fra(X) syndrome confirmed that several of these characteristics (e.g., elongated face, large ears, macroorchidism) do exist in fra(X) syndrome males. Bizygomatic diameter, ear width, and testicular volume were discriminating variables between the 2 groups of males. Thus the importance of a careful physical examination paying particular attention to these physical characteristics and accurately recording the anthropometric measurements when evaluating mentally retarded males is emphasized by our study.

Macroorchidism (testicular volume >2 SD) is a significant finding in most (80%) postpubertal fra(X) males and in approximately 40% of prepubertal males [Hagerman, 1987]. Macroorchidism was found in our fra(X) males [35 (9 prepubertal and 26 postpubertal) of 39 males in our study] but was also present in 25 of 71 mentally retarded males without fra(X) syndrome, although significantly larger testicles were found in the mentally retarded males with fra(X) syndrome than in those without fra(X) syndrome. Thus macroorchidism appears to be a relatively common finding in mentally retarded males. As was discussed by Howard-Peebles and Finley [1983], a syndrome of macroorchidism and mental retardation but without the fra(X) chromosome may be one explanation for those fra(X)-negative mentally retarded males with large testicles. Additional research is needed to explain better the association of macroorchidism in mentally retarded males.

The appearance of large prominent ears in fra(X) males is more likely due to an increased ear width rather than ear length. The finding of prominent ears is also supported by our Z score data with 23 of 39 fra(X) males having an increased ear width (>2 SD), whereas 23 of the 39 males had an increased ear length. This compared with 13 of 71 non-fra(X) males with increased ear width (>2 SD) and 39 of 71 with increased ear length and a positive correlation ($P < .05$) with age. Interestingly, ear width and not ear length entered into the discriminant function and, along with other anthropometric variables, particularly testicular volume and bizygomatic diameter, should be useful in screening for the fra(X) syndrome.

The appearance of large eyes or broad palpebral fissures identified in our earlier photoanthropometric survey of fra(X) syndrome patients [Butler et al., 1988a] is supported in our present study. The average Z score for inner canthal distance was -1.28 , compared with an average Z score of -0.67 for outer canthal distance, indicating a relative narrowing of the inner canthal distance and increased palpebral fissure length.

A narrow face in relation to face length in fra(X) syndrome patients is also supported by our data. The average Z score for bizygomatic diameter was -2.00 and bigonial diameter was -0.99 , whereas the average Z score for face height was 0.03 , lower face height was 0.50 , upper head height was -0.42 , and head height was 0.40 . Nose breadth was also increased (average Z score of 1.54) in relationship to nose length (average Z score of -1.30) or philtrum length (average Z score of 0.71).

Relative macrocephaly has been reported as a manifestation of several fra(X) males [Hagerman, 1987], and our Z score data support a slightly increased head circumference (mean Z score of 0.56) and head breadth (mean Z score of -0.18) of fra(X) males in relation to other parameters [e.g., height (mean Z score of -0.46) and weight (mean Z score of -0.12)] and in comparison with a smaller average head circumference (mean Z score of -0.65) and head breadth (mean Z score of -1.24) seen in our 71 mentally retarded males without fra(X) syndrome. Average Z scores for 4 of the 22 craniofacial parameters were significantly larger ($P < .05$) in the fra(X) than in the non-fra(X) males. Therefore, head parameters (e.g., head breadth) may also be useful as previously unrecognized characteristics for screening individuals for the fra(X) syndrome.

Additional research is needed with a larger sample of males with and without the fra(X) syndrome to test whether the variables entered into the discriminant function in our study will indeed be useful in selecting mentally retarded individuals for fra(X) chromosome analysis. It is encouraging that 97.1% of the individuals in our study sample were correctly classified [33 of 34 fra(X) males and 69 of 71 non-fra(X) males]. Also, in testing the power of discrimination based on the analysis of 13 fra(X) and 50 non-fra(X) males with a second group of fra(X) syndrome (N = 21) and non-fra(X) syndrome (N = 21) males, 95.2% of the test sample of fra(X) syndrome males and 90.5% of the sample of non-fra(X) males were correctly classified. The results of this research are encouraging and should have direct application in screening institutionalized males as well as males with learning or behavioral (e.g., autism) problems. In these groups of individuals the question of fra(X) syndrome is raised, and a better understanding is needed of physical characteristics specific for fra(X) syndrome individuals.

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References

- Blomquist HK, Bohman M, Edvinsson SO, Gillberg C, Gustavson K-H, Holmgren G, Wahlström J. Frequency of the fragile X syndrome in infantile autism: A Swedish multicenter study. *Clin Genet*. 1985; 27:113–117. [PubMed: 3978844]
- Butler MG, Allen GA, Singh DN, Carpenter NJ, Hall BD. Preliminary communication: Photoanthropometric analysis of individuals with the fragile X syndrome. *Am J Med Genet*. 1988a; 30:165–168. [PubMed: 3177441]
- Butler MG, Fletcher M, Gale DD, Meaney FJ, McLeod DR, Fagan J, Carpenter NJ. Metacarpophalangeal pattern profile analysis in fragile X syndrome. *Am J Med Genet*. 1988b; 31:767–773. [PubMed: 3239565]
- Enslein, K., Ralston, A., Wilf, HSC. *Statistical Methods for Digital Computers*. New York: John Wiley and Sons; 1977.
- Farkas, LG. *Anthropometry of the Head and Face in Medicine*. New York: Elsevier Publishing Company; 1981.
- Feingold, M., Bossert, WH. Normal values for selected physical parameters: An aid to syndrome delineation. In: Bergsma, D., editor. *Normal Values for Selected Physical Parameters: An Aid to Syndrome Delineation*. White Plains, NY: The National Foundation—March of Dimes; 1974. p. 1-15. BD: OAS X
- Froster-Iskenius U, Felsch G, Schirren C, Schwinger E. Screening for fra(X)(q) in a population of mentally retarded males. *Hum Genet*. 1983; 63:153–157. [PubMed: 6682403]
- Hagerman RJ. Fragile X syndrome. *Curr Probl Pediatr*. 1987; 17:623–674.
- Hajnis K. Anthropometric standards for the head and face in young children. *Acta Univ Carol Biol*. 1974; 1972:77–294.
- Herskovits, MJ. *Columbia University Contributions to Anthropology*. Vol. XI: *The Anthropometry of the American Negro*. New York: Columbia University Press; 1930.
- Howard-Peebles PN, Finley WH. Screening of mentally retarded males for macroorchidism and the fragile X chromosome. *Am J Med Genet*. 1983; 15:631–635. [PubMed: 6614051]
- Kähkönen M, Leisti J, Thoden CJ, Autio S. Frequency of rare fragile sites among mentally subnormal schoolchildren. *Clin Genet*. 1986; 30:234–238. [PubMed: 3780040]

- Krogman WM. Growth of the head, face, trunk and limbs in Philadelphia white and negro children of elementary and high school age. *Monogr Soc Res Child Dev Serial* 136. 1970; 35:1–80.
- Loesch DZ, Lafranchi M, Scott D. Anthropometry of Martin-Bell syndrome. *Am J Med Genet.* 1988; 30:149–164. [PubMed: 3177440]
- Malina, RM., Roche, AF. *Manual of Physical Status and Performance in Childhood* Vol. 2: Physical Performance. New York: Plenum Press; 1983.
- Meryash DL, Cronk CE, Sachs B, Gerald PS. An anthropometric study of males with the fragile X syndrome. *Am J Med Genet.* 1984; 17:159–174. [PubMed: 6711593]
- National Center for Health Statistics. *Vital and Health Statistics. Public Health Service; Washington, DC: U.S. Government Printing Office; 1970. Skinfolds, body births, biacromial diameter, and selected anthropometric indices of adults, United States, 1960–62. Series 11-No. 35. PHS Publ. No. 1000*
- National Center for Health Statistics. *Vital and Health Statistics. Health Services and mental Health Administration; Washington, DC: U.S. Government Printing Office; 1972. Skinfold thickness of children 6–11 years, United States. Series 11-No. 120. DHEW Publ. No. (HSM) 73-1602*
- National Center for Health Statistics. *Vital and Health Statistics. Health Resources Administration; Washington, DC: U.S. Government Printing Office; 1974a. Skinfold thickness of youths 12–17 years, United States. Series 11-No. 132. DHEW Publ. No. (HRA) 74-1614*
- National Center for Health Statistics. *Vital and Health Statistics. Health Resources Administration; Washington, DC: U.S. Government Printing Office; 1974b. Body dimensions and proportions, white and negro children 6–11 years, United States. Series 11-No. 143. DHEW Publ. No. (HRA) 75-1625*
- National Center for Health Statistics. *Vital and Health Statistics. Public Health Service; Washington, DC: U.S. Government Printing Office; 1979. Weight and height of adults 18–74 years of age, United States, 1971–74. Series 11-No. 211. DHEW Publ. No. (PHS) 79-1659*
- National Center for Health Statistics. *Vital and Health Statistics. Public Health Service; Washington, DC: U.S. Government Printing Office; 1987. Anthropometric reference data and prevalence of overweight, United States, 1976–80. Series 11-No. 238. DHHS Publ. No. (PHS) 87-1688*
- Partington MW. The fragile X syndrome II: Preliminary data on growth and development in males. *Am J Med Genet.* 1984; 17:175–194. [PubMed: 6711594]
- Piedade M, Oliveira MS, Azevedo ES. Racial differences in anthropometric traits in school children of Bahia, Brazil. *Am J Phys Anthropol.* 1977; 46:471–476. [PubMed: 860755]
- Roche, AF., Malina, RM. *Manual of Physical Status and Performance in Childhood. Vol. 1A: Physical Status.* New York: Plenum Press; 1983a.
- Roche, AF., Malina, RM. *Manual of Physical Status and Performance in Childhood. Vol. 1B: Physical Status.* New York: Plenum Press; 1983b.
- Snyder, RG., Schneider, LW., Owings, CL., Reynolds, HM., Gollumb, DH., Schork, MA. *Anthropometry of Infants, Children and Youths to Age 18 for Product Safety Design.* Warrendale, PA: Society of Automobile Engineers, Inc; 1977. SP-450
- Sutherland GR. Heritable fragile sites on human chromosomes: VIII. Preliminary population cytogenetic data on the folic-acid-sensitive fragile sites. *Am J Hum Genet.* 1982; 34:452–458. [PubMed: 7081222]
- Tanner JM, Whitehouse RH. Revised standards for triceps and subscapular skinfolds in British children. *Arch Dis Child.* 1975; 50:142–145. [PubMed: 1130819]
- U.S. Army Natick Research and Development Laboratories. *The Military Handbook of Anthropometry of U.S. Military Personnel. DOD Handbook—Hndbk.* 1980 Oct. 743
- Watson MS, Leckman JF, Annex B, Breg WR, Boles D, Volkmar FR, Cohen DJ, Carter C. Fragile X in a survey of 75 autistic males [letter]. *N Engl J Med.* 1984; 310:1462.
- Weiner, JS., Lourie, JA. *International Biological Programme Handbook No. 9.* Oxford: Blackwell Scientific Publications; 1969. *Human Biology: A Guide to Field Methods.*

Fig. 1.

Bar graphs representing average Z score values for all mentally retarded males with and without the fra(X) syndrome.

Fig. 2.

Histogram depicting 13 white fra(X) and 50 white non-fra(X) syndrome males classified by discriminant analysis. $D = -1.16 + 0.15$ (testicular volume Z score) + 0.36 (ear width Z score) - 0.61 (bizygomatic diameter Z score) + 0.47 (head breadth Z score). Also depicted is the test sample of 21 fra(X) syndrome males and 21 non-fra(X) syndrome males who were ungrouped and did not enter into the discriminant equation but received correct classification rates of 95.2% and 90.5%, respectively, according to the discriminant function produced by the variables entered into the discriminant equation from the 13 fra(X) and 50 non-fra(X) syndrome males.

Fig. 3.

Histogram depicting 34 white fra(X) and 71 non-fra(X) syndrome males classified by discriminant analysis. $D = -1.18 + 0.14$ (testicular volume Z score) $+ 0.35$ (ear width Z score) $- 0.71$ (bizygomatic diameter Z score) $+ 0.32$ (head breadth Z score) $+ 0.40$ (hand breadth Z score) $- 0.30$ (hand length Z score).

TABLE I

Z Score Data (mean $\pm$ SD) for Anthropometric Variables for Mentally Retarded Males With and Without Fra(X) Syndrome

Variable	Fra(X) (range) (N = No. of subjects)	Non-fra(X) (range) (N = No. of subjects)
Age (years) *	27.2 $\pm$ 16.5 (2.6–75.6) (N = 39)	34.0 $\pm$ 11.8 (3.8–71.6) (N = 71)
Weight **	-0.12 $\pm$ 1.62 (-2.36–4.38) (N = 17)	-1.35 $\pm$ 1.06 (-3.34–1.56) (N = 71)
Height **	-0.46 $\pm$ 1.19 (-2.35–2.05) (N = 37)	-1.30 $\pm$ 1.25 (-4.50–1.21) (N = 71)
Sitting height ***	-0.57 $\pm$ 1.36 (-3.31–2.22) (N = 17)	-2.07 $\pm$ 1.30 (-4.97–1.14) (N = 71)
Head circumference ***	0.56 $\pm$ 1.24 (-2.89–2.44) (N = 38)	-0.65 $\pm$ 1.60 (-3.81–3.19) (N = 71)
Head breadth ***	-0.18 $\pm$ 1.24 (-5.00–1.33) (N = 37)	-1.24 $\pm$ 1.39 (-3.67–2.80) (N = 71)
Head length	-0.18 $\pm$ 1.55 (-6.40–2.80) (N = 37)	-0.70 $\pm$ 1.49 (-3.43–3.00) (N = 71)
Minimal frontal diameter	0.52 $\pm$ 1.27 (-1.97–2.64) (N = 17)	0.31 $\pm$ 1.26 (-2.60–4.00) (N = 70)
Auricular head height (vertex-porion)	-1.28 $\pm$ 1.44 (-4.22–1.12) (N = 15)	NA
Upper head height (vertex-nasion)	-0.42 $\pm$ 1.07 (-2.54–1.28) (N = 16)	NA
Head height (vertex-gnathion)	0.40 $\pm$ 1.66 (-1.73–5.34) (N = 16)	NA
Supraorbital diameter (frontosupraorbitale-frontosupraorbitale)	-0.72 $\pm$ 1.58 (-2.64–1.80) (N = 9)	NA
Mandibular arc (tragion-gnathion-tragion)	-0.24 $\pm$ 1.06 (-1.82–1.96) (N = 14)	NA
Depth of lower third of face (tragion-gnathion)	-0.85 $\pm$ 0.99 (-3.06–0.06) (N = 13)	NA
Face height (gnathion-trichion)	0.03 $\pm$ 1.51 (-1.35–3.19) (N = 11)	-0.85 $\pm$ 1.74 (-5.62–2.65) (N = 69)
Lower face height (gnathion-nasion) *	0.50 $\pm$ 1.83 (-2.48–7.14) (N = 38)	-0.41 $\pm$ 1.66 (-5.14–3.00) (N = 71)
Bizygomatic diameter **	-2.00 $\pm$ 1.79 (-5.16–1.15) (N = 35)	-0.82 $\pm$ 1.32 (-4.72–2.00) (N = 71)
Bigonial diameter	-0.99 $\pm$ 1.25 (-3.14–2.04) (N = 35)	-1.08 $\pm$ 0.98 (-3.14–1.29) (N = 70)
Inner canthal distance	-1.28 $\pm$ 1.52 (-5.52–1.63) (N = 37)	-0.87 $\pm$ 1.46 (-4.78–2.63) (N = 70)
Outer canthal distance	-0.67 $\pm$ 1.90 (-4.20–4.33) (N = 37)	-1.31 $\pm$ 2.04 (-5.39–9.06) (N = 70)
Ear length	2.54 $\pm$ 1.69 (-0.38–6.51) (N = 38)	1.94 $\pm$ 1.74 (-2.05–5.66) (N = 71)
Ear width ***	3.19 $\pm$ 2.20 (-0.10–7.05) (N = 37)	0.46 $\pm$ 1.70 (-2.95–4.19) (N = 71)
Nose length	-1.30 $\pm$ 1.19 (-3.55–0.42) (N = 15)	-1.27 $\pm$ 1.53 (-5.45–1.14) (N = 68)
Nose breadth	1.54 $\pm$ 1.63 (-1.63–3.75) (N = 15)	1.15 $\pm$ 1.64 (-3.35–5.12) (N = 68)
Philtrum length	0.71 $\pm$ 1.13 (-1.17–2.58) (N = 14)	NA
Arm span **	-0.49 $\pm$ 1.62 (-2.68–3.58) (N = 35)	-1.36 $\pm$ 1.30 (-4.97–2.08) (N = 68)
Knee-buttock length ***	0.31 $\pm$ 1.41 (-2.00–3.00) (N = 13)	-1.36 $\pm$ 1.49 (-5.00–1.97) (N = 69)
Shoulder-elbow length	-0.06 $\pm$ 1.39 (-2.00–2.65) (N = 17)	-0.36 $\pm$ 1.07 (-3.60–2.18) (N = 71)
Elbow-fingertip length **	0.00 $\pm$ 1.40 (-2.39–2.36) (N = 16)	-1.14 $\pm$ 1.20 (-3.52–1.80) (N = 69)
Wrist breadth	-0.28 $\pm$ 1.16 (-1.67–2.37) (N = 13)	-0.81 $\pm$ 1.34 (-3.67–2.33) (N = 67)
Hand breadth ***	-0.90 $\pm$ 1.41 (-4.00–2.50) (N = 31)	-2.64 $\pm$ 1.47 (-5.25–1.80) (N = 70)
Maximum fist breadth (thumb knuckle-knuckle)	-0.86 $\pm$ 1.42 (-2.43–2.00) (N = 10)	NA
Middle finger length ***	-0.69 $\pm$ 1.26 (-3.40–2.67) (N = 34)	-1.65 $\pm$ 1.10 (-4.00–1.50) (N = 71)
Palm length	-0.53 $\pm$ 1.52 (-3.00–2.82) (N = 25)	-1.00 $\pm$ 1.26 (-5.00–1.91) (N = 62)
Hand length **	-0.62 $\pm$ 1.16 (-3.22–1.50) (N = 33)	-1.33 $\pm$ 1.32 (-5.44–1.44) (N = 71)

Variable	Fra(X) (range) (N = No. of subjects)	Non-fra(X) (range) (N = No. of subjects)
Ankle breadth ***	0.11 ± 0.74 (−1.19–1.94) (N = 13)	−0.98 ± 1.50 (−4.15–3.41) (N = 67)
Foot length ***	−0.51 ± 1.04 (−2.00–2.78) (N = 32)	−1.48 ± 1.16 (−4.00–1.88) (N = 71)
Triceps skinfold	0.48 ± 1.49 (−1.90–3.11) (N = 17)	−0.18 ± 0.73 (−1.27–1.90) (N = 70)
Subscapular skinfold *	0.28 ± 1.18 (−0.93–3.88) (N = 16)	−0.39 ± 0.65 (−1.32–1.65) (N = 70)
Testicular volume ***	8.38 ± 7.12 (0.14–40.26) (N = 38)	2.26 ± 2.77 (−2.75–10.06) (N = 69)
Upper body/lower body segment ratio	0.98 ± 0.07 (0.90–1.15) (N = 15)	NA
Cephalic index (head breadth/head length) × 100	77.65 ± 2.73 (72.86–83.42) (N = 35)	76.65 ± 3.96 (69.79–87.21) (N = 71)

* $P < .05$ (two-tailed independent t test).

** $P < .01$ (two-tailed independent t test).

*** $P < .001$ (two-tailed independent t test).

TABLE II

Correlation Data of Anthropometric Variables Versus Fra(X) Expression and/or Age for Mentally Retarded Males With and Without Fra(X) Syndrome

Variable	Fra(X) Chromosome Expression Correlation (N = No. of subjects)	Age Correlations	
		Fra(X) (N = No. of subjects)	Non-fra(X) (N = No. of subjects)
Weight	-0.37 (N = 17)	-0.22 (N = 17)	-0.05 (N = 71)
Height	-0.18 (N = 32)	-0.25 (N = 37)	0.14 (N = 71)
Sitting height	-0.34 (N = 17)	-0.51 * (N = 17)	-0.04 (N = 71)
Head circumference	0.50 ** (N = 32)	0.19 (N = 38)	0.06 (N = 71)
Head breadth	0.25 (N = 37)	0.16 (N = 32)	0.00 (N = 71)
Head length	0.39 * (N = 32)	0.20 (N = 37)	0.08 (N = 71)
Minimal frontal diameter	0.28 (N = 17)	0.39 (N = 17)	-0.01 (N = 70)
Auricular head height (vertex-porion)	-0.10 (N = 12)	0.03 (N = 15)	NA
Upper head height (vertex-nasion)	-0.24 (N = 12)	-0.07 (N = 16)	NA
Head height (vertex-gnathion)	-0.26 (N = 12)	0.08 (N = 16)	NA
Supraorbital diameter (frontosupraorbitale- frontosupraorbitale)	-0.61 (N = 6)	0.30 (N = 9)	NA
Mandibular arc (tragion-gnathion-tragion)	-0.13 (N = 10)	-0.21 (N = 14)	NA
Depth of lower third of face (tragion-gnathion)	-0.62 (N = 9)	-0.36 (N = 13)	NA
Face height (gnathion-trichion)	0.26 (N = 11)	0.23 (N = 11)	0.04 (N = 69)
Lower face height (gnathion-nasion)	0.17 (N = 32)	0.08 (N = 38)	0.03 (N = 71)
Bizygomatic diameter	0.18 (N = 29)	0.42 * (N = 35)	0.18 (N = 71)
Bigonial diameter	0.03 (N = 29)	0.17 (N = 35)	-0.07 (N = 70)
Inner canthal distance	-0.02 (N = 31)	0.01 (N = 37)	0.03 (N = 70)
Outer canthal distance	0.53 ** (N = 31)	0.20 (N = 37)	-0.01 (N = 70)
Ear length	0.18 (N = 32)	0.54 ** (N = 38)	0.48 *** (N = 71)
Ear width	0.34 (N = 30)	0.62 *** (N = 37)	0.26 * (N = 71)
Nose length	-0.04 (N = 15)	0.38 (N = 15)	0.35 ** (N = 68)
Nose breadth	0.23 (N = 15)	0.22 (N = 15)	0.22 (N = 68)
Philtrum length	0.04 (N = 12)	0.15 (N = 14)	NA
Arm span	-0.01 (N = 31)	-0.11 (N = 35)	-0.10 (N = 68)
Knee-buttock length	-0.50 (N = 13)	-0.72 ** (N = 13)	-0.02 (N = 69)
Shoulder-elbow length	-0.40 (N = 17)	-0.30 (N = 17)	-0.04 (N = 71)
Elbow-fingertip length	-0.17 (N = 16)	-0.44 (N = 16)	-0.03 (N = 69)
Wrist breadth	0.42 (N = 13)	0.08 (N = 13)	0.14 (N = 68)
Hand breadth	0.02 (N = 27)	-0.24 (N = 31)	-0.04 (N = 70)
Maximum fist breadth (thumb knuckle-knuckle)	0.25 (N = 6)	-0.35 (N = 10)	NA
Middle finger length	-0.26 (N = 27)	-0.62 *** (N = 34)	-0.22 (N = 71)
Hand length	-0.22 (N = 27)	-0.50 ** (N = 33)	-0.10 (N = 71)
Ankle breadth	0.03 (N = 13)	0.22 (N = 13)	0.28 * (N = 67)

Variable	Fra(X) Chromosome Expression Correlation (N = No. of subjects)	Age Correlations	
		Fra(X) (N = No. of subjects)	Non-fra(X) (N = No. of subjects)
Foot length	0.05 (N = 27)	−0.23 (N = 32)	−0.08 (N = 71)
Triceps skinfold	−0.09 (N = 17)	0.04 (N = 17)	−0.32 ** (N = 70)
Subscapular skinfold	−0.14 (N = 16)	−0.33 (N = 16)	−0.40 *** (N = 70)
Testicular volume	−0.04 (N = 31)	−0.28 (N = 38)	0.07 (N = 69)
Upper body/lower body segment ratio	0.17 (N = 13)	−0.37 (N = 15)	NA
Cephalic index (head breadth/head length) × 100	−0.18 (N = 31)	0.16 (N = 35)	−0.06 (N = 71)

* $P < .05$.

** $P < .01$.

*** $P < .001$.