CHAPTER 5

METHODOLOGY

5.1 INTRODUCTION

This chapter will outline the technical and statistical methods used in examining, collecting and analysing the data. The problems encountered in this process will also be discussed.

5.2 MEASUREMENT TECHNIQUES

5.2.1 Instruments

Birdsell recorded that the instrumentation used for his fieldwork included an anthropometer, a sliding caliper, and a spreading caliper made to the pattern of P. Herman of Zurich and a steel metric tape. They were checked before and after the field sessions and found to be accurate (Birdsell, 1941: iii). Weight was measured with a portable spring scale that was calibrated on a regular basis with a known weight (Birdsell, 1941: iii).

5.2.2 Technique

In the first expedition 26 measurements of the body, head and face were taken on each individual, however during the second expedition a number of these were discarded. The most serious omission was that bi-iliac breadth, measured in the first expedition only. This has limited the variable's use in some of the statistical analyses in this study.

Not all of the measurements recorded by Birdsell are used in this analysis and only those used herein will be documented. The measurements were taken using the Harvard technique: a combination of the techniques of Martin (Martin 1928), abbreviated as 'M' and Hooton (1939), abbreviated as 'H', with a few modifications of Birdsell's own (eg. direct limb measurements instead of subtractive ones) (Birdsell 1941: iv-v). There are three separate sources for Birdsell's methodology: his 1941 PhD dissertation (Birdsell 1941), a set of unpublished notes held at the South Australian Museum and his 1993 monograph (Birdsell 1993). The variables are presented with their full name, followed, if appropriate, by an abbreviation in brackets. Tables 5.1 and 5.2 and Figures 5.1-5.2 provide written and visual descriptions of the anthropometric points and measurement techniques as recorded by Birdsell (1941, 1993). Weight was originally measured in pounds but has been converted to kilograms. All other measurements are in millimetres.

Table 5.1: Definitions of anthropometric points

Anthropometric/ Anatomical Landmark	Abbreviation	Definition	Source
BODY			
Acromion	a	Most lateral margin of the lateral borders of the acromial process of the scapula	Olivier, 1969: 17; Knussmann, 1988: 240.
Iliocristale	ic	Most lateral point of the iliac crest.	Olivier, 1969: 18; Knussmann, 1988: 241.
Radiale	r	Most proximal point on the capitulum of the radius.	Lohman, *et al.*, 1991: 9; Knussmann, 1988: 242.
Sphyrion	sph	Most distal point of the medial malleolus of the tibia.	Lohman, *et al.*, 1991: 10; Knussmann, 1988: 243.
Stylion	sty	Most distal point of the lateral margin of the styloid process of the radius.	Lohman, *et al.*, 1991: 10; Knussmann, 1988: 242.
Tibiale (internum)	ti	Most proximal point on the medial border of the medial condyle of the tibia.	Lohman, *et al.*, 1991: 10; Knussmann, 1988: 243.
Tibiale externum	tie	Most proximal point on the lateral border of the lateral condyle of the tibia.	Knussmann, 1988: 243
Trochanterion	tro	Most proximal point on the greater trochanter of the femur.	Lohman, *et al.*, 1991: 11; Knussmann, 1988: 241.
HEAD			
Euryon	eu	Bilateral points marking the maximum bi-parietal breadth of the cranium.	Knussmann, 1988: 234; Krogman and Iscan, 1986: 519.
Frontotemporale	ft	Bilateral points marking the most medial points on the linea temporalis of the frontal bone.	Farkas 1994: 21; Knussmann, 1988: 234.
Glabella	gl	The most anterior midline point of the cranium when in the Frankfort Horizontal plane.	Knussmann, 1988: 234; Brown, 1989: 10.
Opisthocranion	opc	The point marking maximum skull length as measured from glabella	Knussmann, 1988: 234; Brown, 1989: 10
Vertex	v	The highest point on the vault in the median sagittal plane with the skull in the Frankfort Horizontal.	Knussmann, 1988: 234.

Table 5.1: Definitions of anthropometric points

Anthropometric/ Anatomical Landmark	Abbreviation	Definition	Source
FACE			
Alae	al	Most lateral point on the ala of the nose.	Farkas, 1994: 25; Knussmann, 1988: 237.
Gnathion (Menton)	gn	Lowest, midline point on the inferior border of the mandibular symphysis (chin).	Knussmann, 1988: 236; Brown 1989 10.
Gonion	go	Most prominent point on the angle of the jaw.	Farkas, 1994: 21; Knussmann, 1988: 236.
Infra-dentale (Incision)	id	Point on the alveolar border between the lower central incisors.	Bräuer, 1988:167.
Nasion	na	Junction of internasal suture with the nasofrontal suture.	Knussmann, 1988: 235; Brown, 1989: 11.
Prosthion	pr	The lowest tip on the bony septum between the upper central incisors.	Knussmann, 1988: 238; Brown, 1989: 11.
Subnasale	sn	Apex of the angle formed by the lower margin of the nasal septum and the philtrum.	Farkas, 1994: 23; Knussmann, 1988: 237.
Tragion	t	The notch on the ear where the superior free border of the tragus meets the helix.	Farkas, 1994: 25; Knussmann, 1988: 238.
Zygion.	zy	The most lateral point on the zygomatic arch.	Knussmann, 1988: 236; Brown, 1989: 15.

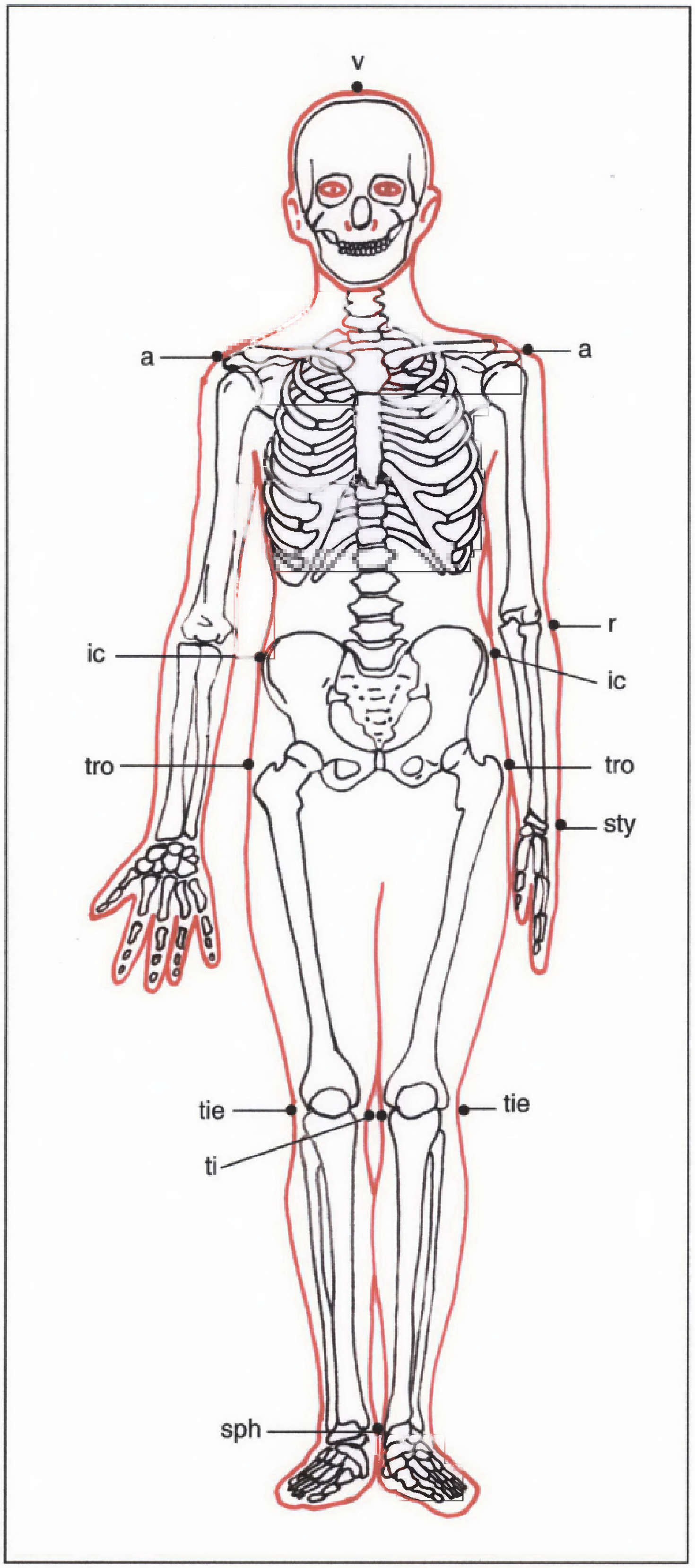


Figure 5.1: Anatomical points of the body as mentioned in the text.

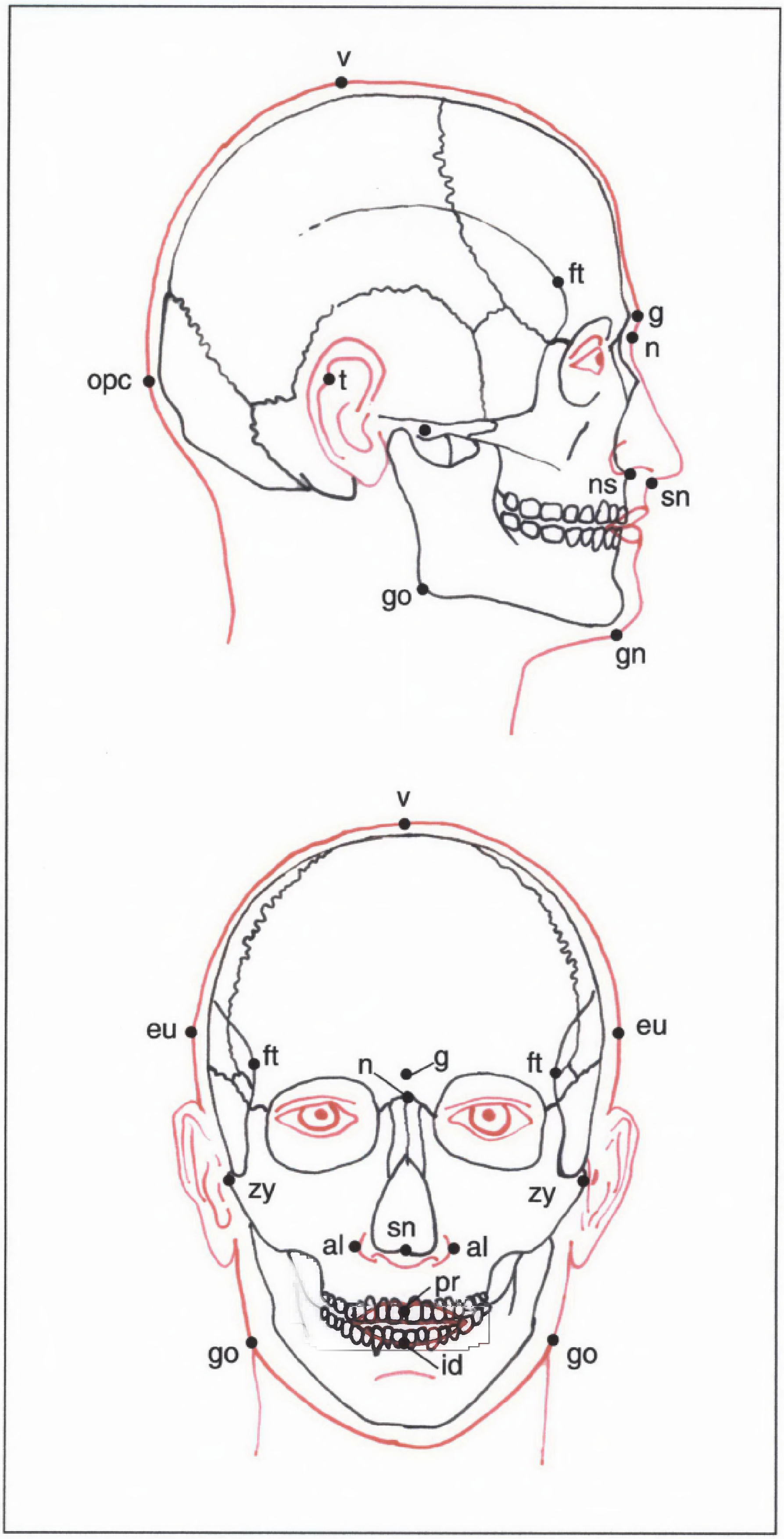


Figure 5.2: Anatomical points of the head and face as mentioned in the text.

Table 5.2: Definitions of anthropometric measurements

Measurement	Synonyms	Instrument	Technique	Source
BODY				
Weight		Spring Scale	The subjects were weighed without heavy clothing and shoes. Up to 7 pounds was subtracted for clothing weight.	Birdsell, 1941;1993
Stature		Anthropometer	Ground to vertex. Shoes and thick socks removed.	Martin, 1928 (M-1); (H-2); Birdsell, 1941;1993.
Femur Length (Fem L)		Anthropometer used as a sliding caliper.	Trochanterion to tibiale externum, above and slightly anterior to the fibular head, on the lateral line of the tibiofemoral articulation. (tro-tie)	Martin, 1928 (M-55-1), Birdsell, 1941;1993; Knussmann ,1988: 268 (55-1)
Tibia Length (Tib L)		Anthropometer used as a sliding caliper.	Tibiale to sphyrion, medial aspect. (ti-sph)	Martin, 1928 (M-56a); Birdsell, 1941;1993; Knussmann, 1988: 268 (56a)
Humerus Length (Hum L)	Upper arm length	Anthropometer used as a sliding caliper.	From a point on the inferior aspect of the acromial point to radiale. (a*-r) Birdsell notes that his location of acromion might be somewhat non-standard when measuring humerus length.	Birdsell, 1941;1993; Knussmann, 1988: 266 (47)
Radius Length (Rad L)	Forearm length; lower arm length	Anthropometer used as a sliding caliper.	Radiale to stylion. (r-sty)	Martin, 1928 (M-48); Birdsell, 1941;1993; Knussmann, 1988: 266 (48)
Sitting Height (Sit H)		Anthropometer.	Vertex to the level of the surface upon which subject is sitting.	Martin, 1928 (M-23); Hooton, 1939 (H-6); Birdsell, 1941;1993; Knussmann, 1988: 262 (23)
Biacromial Diameter (Biac)	Shoulder breadth	Anthropometer used as a sliding caliper.	Breadth between the right and left acromial processes. (a-a)	Martin, 1928 (M-35) Hooton, 1939 (H-3) Birdsell, 1941;1993; Knussmann, 1988:263 (35)
Bi-iliac Diameter (Bi-iliac)	Pelvic breadth; biiliocristal diameter	Anthropometer used as a sliding caliper.	Maximum breadth between the right and left iliocristalia. (ic-ic)	Martin, 1928 (M-40); Birdsell, 1941; Knussmann, 1988: 264 (40)
Calf Circumference (Calf C)		Steel metric tape.	Maximum calf circumference in a plane normal to the tibial axis.	Martin, 1928 (M-69); Birdsell, 1941; Knussmann, 1988: 272 (69)
HEAD				
Head Length (Head L)		Spreading caliper.	Glabella to opisthocranion in the median sagittal plane. (gl-opc)	Martin, 1928; (M-1) Hooton, 1939; (H-7) Birdsell, 1941; 1993. Knussmann, 1988: 244 (1)
Head Breadth (Head B)	Bi-parietal breadth	Spreading caliper.	Maximum breadth of the head perpendicular to the median sagittal plane, above supramastoidal crest. (eu-eu)	Birdsell, 1941; 1993. Knussmann, 1988: 245 (3)
Head Height (Head H)		Anthropometer used as Sliding caliper.	From the left tragion to vertex, with the head held in the ear-eye plane. (t-v)	Hooton, 1939. Birdsell, 1941; 1993; Farkas, 1994:29 (P-15)
Minimum Frontal Diameter (Min Front D)	Forehead width	Spreading caliper.	Minimum distance between the temporal crests on the frontal bone, from right to left frontotemporale. (ft-ft)	Hooton, 1939 (H-11), Birdsell, 1941; 1993. Knussmann, 1988: 245 (4).

Table 5.2: Definitions of anthropometric measurements

Measurement	Synonyms	Instrument	Technique	Source
FACE				
Bizygomatic Diameter (Bizyg)	Face width	Spreading caliper.	Maximum diameter between the zygomatic arches, from right to left zygion. (zy-zy)	Martin, 1928 (M-6); Hooton, 1939 (H-12); Birdsell, 1941; 1993; Knussmann, 1988: 245 (6)
Bigonial Diameter (Bigon)	Lower face width	Spreading caliper.	Diameter between right and left gonia. Care is taken to avoid including any of the masseter muscle mass. (go-go)	Martin, 1928 (M-8); Hooton, 1939 (H-17); Birdsell, 1941; 1993; Knussmann, 1988: 245 (8).
Total Facial Height (Tot Fac H)	Morphological facial height	Sliding caliper.	Distance from nasion to gnathion (menton), with mouth closed and teeth in occlusion. (na-gn)	Martin, 1928 (M-18); Hooton, 1939 (H-13); Birdsell, 1941; 1993; Knussmann, 1988: 248 (18)
Upper Facial Height (Upp Fac H)	Morphological upper facial height	Sliding caliper.	Distance from nasion to upper alveolar point (prosthion). Where upper incisors were missing, the alveolar point was estimated. (na-prn)	Martin, 1928 (M-20); Hooton, 1939 (H-14); Birdsell, 1941; 1993; Knussmann, 1988: 248 (20)
Nose Height (Nose H)		Sliding caliper.	Distance from nasion to subnasale. Piercing of the nasal septum was not found to affect this measurement. (na-sn)	Martin, 1928 (M-21); Hooton, 1939 (H-15); Birdsell, 1941;1993; Knussmann, 1988: 248 (21)
Nose Breadth (Nose B)		Sliding caliper.	Distance between right and left nasal alaria, giving maximum contact breadth without compression. (al-al)	Martin, 1928 (M-13); Hooton, 1939 (H-16); Birdsell, 1941; 1993; Knussmann, 1988: 246 (13).
Nose Depth (Nose D)		Sliding caliper.	Radius of projection of the nasal structure from the nasal plane. "The axis of the caliper is determined by one parallel to the median sagittal plane, and by another perpendicular to the profile of the nasal bridge. The proximal point of the caliper is moved so that by sighting along it with one eye it becomes tangential to the nasal profile. The value determined in this way represents the projection of the nasal structure from the nasal plane." Measurement developed by Birdsell.	Birdsell, 1941; 1993.
Mandibular Depth (Mand D)	Height of mandibular symphysis.	Sliding caliper.	Distance from incision to gnathion (menton). This measurement is more commonly performed on skeletal rather than living subjects (id-gn)	Bräuer 1988: 183 (69); Birdsell, 1941; 1993.

Table 5.3: Calculated indices of the body, head and face

Index Name	Formula	Source
BODY		
Surface Area (SA)	Surface Area (cm^2) = Weight(kg)$^{0.425}$ * Stature$^{0.725}$(cm) * 71.84	Dubois and Dubois, 1916
Surface Area to Weight Ratio (SA/Weight)	Surface Area (cm^2)/Weight (kg)*100	Ruff, 1991:82-83
Relative Pelvic Breadth (RPB)	Bi-iliac Breadth (mm)/Stature (mm)	Knussmann, 1988: 276
Relative Shoulder Breadth (RShB)	Biacromial Breadth (mm)/Stature (mm)*100	Knussmann, 1988: 276
Relative Sitting Height (RSitH)	Sitting Height (mm)/Stature (mm)*100	Knussmann ,1988: 274
Birdsell's Ponderal Index (PI)	Stature (cm)/ $\sqrt[3]{\text{Weight}}$ (kg)	Birdsell, 1993
Calf/Tibial (Calf/Tib)	Calf Circumference (mm)/Tibial Length(mm)*100	Knussmann, 1988: 276; Birdsell, 1941;1993
Radio-Humeral (Rad/Hum)	Radius Length (mm)/Humerus Length(mm)*100 (not analogous to brachial index in Knussmann 1988:275)	Birdsell, 1941;1993
Tibio-Femoral (Tib/Fem)	Tibia Length (mm)/Femur Length(mm)*100 (not analogous to crural index in Knussmann 1988:275).	Birdsell, 1941;1993
Intermembral (Interm)	Radius+Humerus L(mm)/Tibia+Femur L(mm)*100 (not analogous to intermembral index in Knussmann 188:275, which is arm length/leg length, but similar to the index used by Macho and Freedman (1987).	Birdsell, 1941;1993
Femur-Sitting Height (Fem/SitH)	Femur Length (mm)/Sitting Height (mm)*100	Birdsell, 1993
Tibia-Sitting Height (Tib/SitH)	Tibia Length (mm)/Sitting Height (mm)*100	Birdsell,1993
Humerus-Sitting Height (Hum/SitH)	Humerus Length (mm)/Sitting Height (mm)*100	Birdsell, 1993
Radius-Sitting Height (Rad/SitH)	Radius Length (mm)/Sitting Height (mm)*100	Birdsell, 1993
HEAD AND FACE		
Cephalic Index (CI)	Head Breadth (mm)/Head Length (mm)*100	Knussmann, 1988: 256
Cranial Module (CM)	Head Length(mm)+Head Breadth(mm)+Head Height (mm)/3	Birdsell, 1941;1993
Nasal Index Breadth (NIB)	Nasal Breadth (mm)/Nasal Height (mm)*100	Knussmann, 1988:257
Nasal Index Depth (NID)	Nasal Depth (mm)/Nasal Breadth (mm)*100	Birdsell, 1941;1993
Cephalo-Facial (CFI)	Bizygomatic Diameter (mm)/Head Breadth (mm)*100	Knussmann, 1988: 256
Total Facial (TFI)	Total Facial Height (mm)/Bizygomatic Diameter (mm)*100	Knussmann, 1988: 256

5.2.3 The Calculation of Indices

Indices of the body, head and face are listed in Table 5.3. Most of these are fairly standard anthropometric ratios used to assess body shape. Some have been adapted from osteometric indices and do not conform exactly to anthropometric norms and some were formulated by Birdsell (1941; 1993).

One particular departure from a published equation is that of Ponderal Index, also known as Livi's Index. In Knussmann (1988: 277) and Olivier (1969: 41) the index is formulated as $PI = \sqrt[3]{\text{Weight (kg)}} * 10 / \text{Stature (m)}$. Birdsell (1993: 313), however, calculates it as $PI = \text{Stature (cm)} / \sqrt[3]{\text{Weight (lbs.)}}$. This of course gives an inverse ratio to Livi's Index and the correlation coefficient *r* between the two indices is slightly less than one. For the purpose of this analysis Birdsell's formula was used inserting kilograms rather than pounds to measure weight. This change is irrelevant to the results, as a correlation between the index calculated with pounds and that calculated with kilograms is approximate to unity.

Another area of note is the equation used to estimate body surface area. Directly measuring the surface area of the human body is difficult and time consuming. Because of surface area's known correlation to basal metabolic rate - a baseline measurement important in areas of applied physiology and clinical medicine - methods have been developed to estimate surface area using commonly and easily obtained anthropometric measurements. One of these attempts, and a method still widely used, is that of Dubois and Dubois (1916). The Dubois claimed an average accuracy of ±1.5% for their estimate of surface area and a maximum error for the estimate of ±5% (Dubois and Dubois, 1916: 869-871). They cautioned that the maximum error would apply to individuals with a "very unusual body shape" (1916: 866). Further testing by a number of researchers has also found estimate errors in certain ethnic groups, particularly Japanese and Chinese (Dubois 1936; Necheles and Loo 1932; Stevenson 1928; Takahira & Kitagawa 1924; Waddell *et al.* 1928) and various corrections and updates of this formula have been produced (Bannerjee & Sen 1955; Boyd 1935; Gehan & George 1970; Haycock *et al.* 1978; Mehra 1958; Takai & Shimaguchi 1986). Whilst some studies have suggested that the deviations from true surface area were unimportant and use of the original formula was to be recommended (Martin *et al.* 1984; Rodahl 1952), Nwoye found that most of the published equations seriously underestimated the true surface area of Black Africans by between 6% and 22% (Nwoye 1989). His reformulated equation increased the influence of stature in the estimation of surface area. This, he contended, was due to important differences in body shape between Africans and Europeans. Further, he found that of the other published equations, the next most accurate was that formulated using Indian subjects (Bannerjee & Sen, 1955; Mehra, 1958) who also have linear physiques.

Table 5.4: Estimates of body surface area for Birdsell's Australians using the three different formulae.

Group	Weight (kg)	Stature (mm)	SA (D&D)	SA (G&G)	SA (Nwoye)
1	60.14	1635.60	1.65	1.66	1.49
2	57.53	1638.07	1.62	1.62	1.48
3	65.99	1652.68	1.72	1.74	1.53
4	60.90	1639.81	1.66	1.68	1.50
8	63.18	1635.27	1.68	1.70	1.50
9	64.80	1665.33	1.72	1.74	1.54
10	65.46	1639.48	1.71	1.74	1.52
11	63.00	1653.30	1.69	1.71	1.52
12	65.42	1686.04	1.74	1.76	1.57
13	59.78	1659.05	1.66	1.67	1.51
14	71.31	1720.43	1.83	1.85	1.64
15	62.77	1677.15	1.71	1.72	1.55
16	68.42	1715.13	1.80	1.80	1.62
17	59.64	1623.67	1.63	1.65	1.47
18	50.52	1594.33	1.50	1.50	1.39
19	47.91	1550.03	1.44	1.45	1.33
20	52.70	1590.68	1.53	1.53	1.40
21	56.94	1622.19	1.60	1.61	1.46
22	60.88	1657.55	1.67	1.68	1.51
23	57.53	1661.52	1.64	1.63	1.50
24	58.97	1666.96	1.66	1.66	1.52
25	56.75	1666.94	1.63	1.63	1.51
26	64.79	1736.46	1.77	1.77	1.62
27	66.86	1709.36	1.77	1.78	1.60
28	60.53	1698.86	1.69	1.69	1.56
29	62.75	1680.57	1.71	1.72	1.55
30	57.69	1704.41	1.67	1.66	1.55
31	57.08	1706.14	1.66	1.65	1.55
32	66.41	1746.57	1.80	1.80	1.64
33	55.66	1665.21	1.62	1.61	1.50
34	61.39	1662.36	1.68	1.69	1.52
35	58.64	1671.73	1.66	1.66	1.52
36	61.60	1642.24	1.67	1.69	1.50
37	55.87	1663.90	1.62	1.61	1.50
38	60.96	1674.95	1.68	1.69	1.54
39	63.66	1698.54	1.73	1.74	1.58
40	61.25	1706.28	1.71	1.71	1.57
41	72.53	1741.21	1.87	1.88	1.67
42	67.32	1712.83	1.78	1.79	1.61
43	63.58	1693.09	1.73	1.73	1.57
44	58.43	1630.25	1.62	1.64	1.47
45	66.82	1713.33	1.78	1.79	1.61
46	62.89	1695.09	1.72	1.72	1.57
47	59.20	1737.85	1.71	1.69	1.60
48	69.17	1736.90	1.82	1.83	1.65
49	60.89	1693.29	1.70	1.70	1.56
50	62.51	1746.07	1.76	1.74	1.62
51	55.59	1700.83	1.64	1.62	1.54
52	70.47	1732.44	1.84	1.85	1.65
53	63.11	1764.23	1.78	1.76	1.65
54	58.65	1691.67	1.67	1.66	1.54
55	64.01	1769.00	1.79	1.77	1.66
56	64.40	1709.54	1.75	1.75	1.59
57	74.60	1701.22	1.86	1.89	1.63
58	68.71	1683.09	1.78	1.80	1.58
59	65.61	1760.33	1.80	1.79	1.66
60	61.14	1683.20	1.70	1.70	1.55

The equations used in Table 5.4 are:

Dubois and Dubois (1916): $\text{SA (m}^2) = .007184 * \text{Stature}^{0.725} \text{(cm)} * \text{Weight (kg)}^{0.425}$

Gehan and George (1970): $\text{SA (m}^2) = 0.02350 * \text{Stature (cm)}^{0.422} * \text{Weight (kg)}^{0.515}$

Nwoye (1989): $\text{SA (m}^2) = 0.001315 * \text{Stature (cm)}^{1.2139} * \text{Weight (kg)}^{0.2620}$

This may have important implications when estimating surface area in Australian Aborigines as they, like Africans and Indians, tend to be more linear than Europeans. In order to assess these differences, several of the equations were applied to Birdsell's male sample. As is demonstrated in Table 5.4, the Dubois and Dubois (1916) equation produces similar results to those resulting from Gehan and George (1970). Nwoye's equation, however, gives consistently lower estimates than the other two, but given the lack of any independent measure of surface area in Aboriginal people, it is not possible to gauge the accuracy of one or other of the equations. As a result, the equation of Dubois and Dubois was chosen as the most general: as one that could be applied to all ethnic groups in the world sample.

5.3 TECHNIQUES USED BY OTHER OBSERVERS

5.3.1 Australia

Adelaide University

Campbell and Hackett (Campbell & Hackett 1927) record that their measurements follow the International Agreement (Hrdliçka 1920), as do those of Wood-Jones and Lewis and Fenner (Campbell & Lewis 1926; Fenner 1936; Wood-Jones & Campbell 1924). It is apparent, however, that some measurements vary considerably from those taken by Birdsell. Limb segment lengths, for instance, were subtractive rather than direct measures, and are not comparable.

Birdsell did include some of the Adelaide data in his 1993 monograph. Of the somatic measurements he deemed only Weight and Stature comparable. In a statistical comparison of Birdsell's and Adelaide University's measurements of the Warlpiri in Table 5.5, a somewhat different picture emerges. Given the small sample sizes, the level of significance for rejection has been set at the 1% level, although those significant at the 5% level have been included for reference purposes. Here we can see that all variables except Stature and Sitting Height are statistically comparable, but it is possible that some sort of secular change (due to changes in lifestyle) might be implicated in these significant differences in body height (Barrett & Brown 1977; Brown 1976). The Adelaide University measurements on the Warlpiri were taken during the "G" (1931) and "L" (1936) expeditions, up to thirty years before those of Birdsell, and all measurements are smaller in the earlier sample.

Abbie

In his published works, Abbie variously refers to his techniques as complying with the standard of Martin (Abbie 1975) and to IBP standards (Abbie 1977), however, given that a "standard" set of measurements means different things to different observers, this is not an adequate description of technique. From Table 5.5, it is clear that his measurements vary considerably with those of Birdsell, particularly Sitting Height, Humerus Length and Radius Lengths. Macho and Freedman (1987: 3-4) have also commented on his technique, and the difference seen in Sitting Height has previously been discussed by Birdsell (1993: 318). Given the differences in sitting height between Birdsell's and Abbie's samples, the latter's measurements for this variable will not be utilised in the comparative world sample, nor will those taken on the limbs.

Table 5.5: Comparison of Birdsell, Abbie and Adelaide University Measurements for the Warlpiri

	Birdsell			**Abbie**			**Adelaide University**			***t*-tests**	
Variable	**n**	**X**	**sd**	**n**	**X**	**sd**	**n**	**X**	**sd**	***t* JB/AA**	***t* JB/AU**
Weight	13	59.20	5.07	24	55.81	7.48	9	56.34	4.80	1.46	1.33
Stature	13	173.78	5.84	24	169.24	5.6	27	168.29	4.41	2.32*	3.32 **
Hum L	13	345.46	18.15	24	311.5	20.6	.	.	.	4.98***	.
Rad L	13	279.85	11.62	24	262.2	17.6	.	.	.	3.24**	.
Fem L	13	488.38	15.47	24	464.3	32.7	.	.	.	2.50*	.
Tib L	13	420.15	19.62	24	406.5	24.7	.	.	.	1.72	.
Biac	13	359.31	17.71	24	343.9	18.6	26	347.85	15.01	2.45*	2.12*
Biiliac	.	.	.	24	257.0	17.8	11	261.73	11.54	.	.
Sit H	13	861.08	29.74	24	787.4	41.5	27	822.93	35.05	5.65***	3.38**
Calf C	12	298.33	17.32	.	.	.	11	293.55	14.15	.	0.72

Warner

According to Birdsell (1993), there is no extant list of Warner's measurement techniques. Birdsell examined Warner's data for his 1993 monograph and concluded that there were certain differences between his measurements and those of Warner. He stated that:

> "It is not known who trained Warner in anthropometry, but his techniques were grossly in error in some measurements." (Birdsell 1993: 26).

These differences, however, related to cranio-facial measurements, which will not be used in the world comparative sample.

5.3.2 World

Hiernaux

Hiernaux (1976: 17-19) states that he used the techniques of Martin and Saller (1957). This applied to the data he collected personally and to those data collected by other observers that he included in his study. All measurements listed should be comparable to those of Birdsell. Hiernaux noted, however, that some values for sitting height were measured with a non-standard technique (Hiernaux, 1968: 17) and these have been deleted from this analysis.

Eveleth and Tanner

This is a compilation of many authors' works, however all those selected followed IBP standards, and given the limited set of body measurements presented, they should be comparable to Birdsell's variables (Eveleth and Tanner, 1976).

Edholm

The only variables taken from Edholm (1966) are Weight, Stature and Sitting Height. Although Edholm does not record the measurement techniques used, Weight and Stature should be comparable with Birdsell's measurements. It is less certain that sitting height will be comparable, but it has been included in order to increase the sample sizes for sitting height and relative sitting height in the world sample.

Littlewood

Littlewood's methods are set out in Appendix 1 of his 1972 paper (Littlewood 1972: 97-103). He cites Hooton (1946) as his main technical reference, however his technical descriptions are not detailed. It is apparent that the measurements of lower limb segment lengths were subtractive, therefore not comparable to Birdsell's limb measurements. Upper limb segment lengths appear to have been taken directly, but there are no further details.

Other

The methods of Ai *et al.*, (1993) and Dai *et al.*, (1996) are well documented in their respective papers and most variables are comparable with those of Birdsell.

5.4 OSTEOMETRIC METHODS

5.4.1 Metrical Variables and Measurement Techniques

Except where otherwise stated, standard measurement procedures and equipment (Brown 1989; Howells 1973b; Martin 1928; Martin & Saller 1957) were used throughout. Measurements reported here were recorded by Peter Brown, with standard anthropometric instruments and techniques. Those taken from Trinkaus (1981) are also comparable.

Table 5.6: Definitions of osteometric measurements

Measurement	Synonyms	Instrument	Technique	References
Post-crania				
Maximum Humerus length	Maximum Morphological Length of Humerus	Osteometric Board	Length from the head to the most distant point on the trochlea.	Bräuer, 1988: 199 (1); Krogman and Iscan, 1986: 524.
Maximum Radius Length	Maximum Morphological Length of Radius	Osteometric Board	Maximum length from the top margin of the head to the tip of the styloid process. Measurement taken parallel to the shaft.	Bräuer, 1988: 201 (1); Krogman and Iscan, 1986: 526.
Maximum Femur Length		Osteometric Board	Maximum length of from the head to the medial condyle .	Bräuer, 1988: 216 (1); Krogman and Iscan, 1986: 526.
Physiological Femur Length	Oblique Length, Bicondylar Length	Osteometric Board	The length of the femur from a plane connecting the medial and lateral condyles to the most distant point on the head of the femur.	Bräuer, 1988: 216 (2); Krogman and Iscan, 1986: 526.
Maximum Tibia Length	Maximum Morphological Length of Tibia	Osteometric Board	The maximum length from the intercondylar eminences to the tip of the medial malleolus. Measurement taken parallel to the shaft.	Bräuer, 1988: 220 (1a); Krogman and Iscan, 1986: 528.

Instruments column only refers to techniques of Brown (1989).

5.5 STATISTICAL AND GRAPHICAL PROCEDURES

5.5.1 Methodologies Used in Previous Studies.

The results of previous research into ecogeographic variation were covered in Chapter 3, however here I will briefly review the statistical methods used in these studies.

The earliest research was focused on non-human animals and was empirical in nature, based on the observations of zoologists, that animals in colder climates were larger (Bergmann's Rule) and had shorter limbs (Allen's Rule) than those in warmer climates.

The next stage in this research involved the quantification of the relationship, however its nature remained empirical rather than theoretical (Mayr 1963). Statistical methods were applied to this field relatively soon after their formulation, around the turn of the century. One of the earliest quantitative studies was that of Thomson (1913), who along with Buxton (Thomson and Buxton 1923), examined the relationship between nasal shape and climate using correlation and regression. Throughout the early 20th Century descriptive studies examining the plasticity and adaptive significance of the human form with regard to environment continued to be published (Boas 1912; Coon, Garn, & Birdsell 1950; Lasker 1946, 1952). But it was not until the 1950s, with the advent of high speed computing, that research examining the relationship between human body size and shape and climate, using correlation, regression and allied techniques, became more prevalent (Newman & Munro 1955; Roberts 1952, 1953; Weiner 1954)

Bivariate techniques

By far the most common statistical methods used to assess the association between morphological and climatic variables are correlation and regression. Various studies have used the parametric correlation coefficients of Pearson's Product-Moment (Beals *et al.* 1983; Beals *et al.* 1984; Carey & Steegmann 1981; Crognier 1981a; Davies 1932 Endo *et al.* 1993; Guglielmino-Matessi *et al.* 1979; Hiernaux 1968; Hiernaux & Froment 1976; Holliday 1997b; Holliday & Falsetti 1995; Jacobs 1985b: Katzmarzyk & Leonard 1998; Macho & Freedman 1987; Newman & Munro 1955; Reinbold *et al.* 1985; Roberts 1952, 1953, 1973; Ruff 1991, Ruff 1994; Shea 1977; Thomson & Buxton 1923; Trinkaus 1981; Walter 1976; Weiner 1954) and Zero Order (Crognier 1981b; Newman 1960), calculated using raw scores, or the arithmetic means of raw scores. Partial correlation has been used to assess the affect of variables that might be inter-correlated with those being studied (Carey & Steegmann 1981; Endo *et al.* 1993; Holliday & Falsetti 1995; Newman & Munro 1955; Roberts 1952, 1953, 1973; Ruff 1991, 1994). On at least two occasions, non-parametric measures of association (Kendall's *Tau*) have also been used, usually where non-normal distribution of variables is of concern to the researcher (Guglielmino-Matessi *et al.* 1979; Stinson 1990). In a recent study on the effects of climate on bone aging, Belkin *et al.* (1998) used both Pearson's *r* and Spearman's *Rho*. However, apart from these exceptions few studies have explored the possibility of inflation or deflation of correlations due to the non-normal distribution of variables (usually climate variables) and taken steps to overcome this. Roberts warned that the correlation coefficients recorded in his papers were, at best, only indicators of the size and direction of the associations between body morphology and climate, but he did not explore this statement further (Roberts 1973). Hiernaux acknowledged that his data on rainfall was significantly skewed and used a log transformation in order to overcome this (Hiernaux 1968). As mentioned above, Stinson (1990) used Kendall's *Tau*, rather than Pearson's *r*, because of the lack of normal distribution in her climate variables.

Multivariate techniques

Multivariate techniques have been used to explore the complexity of the adaptive response to environmental factors. Multiple correlation and regression (Thomas and Buxton, 1923; Roberts, 1953; Newman & Munro, 1955; Newman, 1960; Carey & Steegman, 1981; Endo *et al.*, 1993; Hernanadez *et al.* 1997; Belkin *et al.*, 1998) and stepwise multiple regression (Crognier 1981b; Macho & Freedman 1987) have been used to assess both the possibility of cumulative effects of climate variables on body morphology, as well as trying to identify the primary climatic stressor.

Another technique to overcome complexity is to apply multivariate techniques to the raw data before further analysis. Principal components have been extracted from climate variables (Guglielmino-Matessi *et al.* 1979; Holliday & Falsetti, 1995; Belkin *et al.*, 1998) and morphological variables (Holliday 1997b), and ecogeographic correlations have been calculated from the component scores . Holliday took the further step of transforming his morphological variables into "log size and shape" (logged raw scores) and "log shape", prior to extracting the principal components. These shape variables had "size" removed through standardisation to the log geometric mean, using the technique of Mossiman and James (1979). Indeed the Mossimann and James developed their size transformed variables to assess the degree of climatic adaptation in Red-Winger Blackbirds. Guglielmino-Matessi *et al.*. (1979) used Howell's canonical variates for their morphological variables, and Crognier assessed the association between paired geographical, morphological and climatic Mahalanobis D^2 distances between his study groups (Crognier, 1981a) to assess the effect of climate.

5.5.2 Methods used in this analysis

The primary aim of this thesis is to explore the relationship between human body size and shape and the environment, in particular climate. In order to fulfil this aim various statistical methods have been used to assess the magnitude, direction and significance of the association between the selected anthropometric and climate variables.

5.5.2.1 Descriptive and Exploratory Statistics

Prior to conducting the statistical analyses, all population samples were examined for error, outliers and normal distribution using standard exploratory and graphical techniques (Devore & Peck 1986; Hoaglin *et al.* 1983; Tukey 1977). Initial examination of the data included the use of stem and leaf plots, frequency histograms and box and whisker plots (Tukey 1977).

Many of the statistical techniques used in this analysis are sensitive to non-normal distributions (Devore & Peck, 1986). Along with skew and kurtosis, outlying values can affect normal distribution, therefore outliers were examined for correctness of entry. If the error had occurred in the data entry stage, the value was corrected. If an extreme value was obviously incorrect, it was deleted from the data set. Tests for normal distributions were generated for each population sample by SPSS 6.1.1 EXPLORE function. These included Shapiro-Wilks, for samples less than or equal to $n = 50$ (Shapiro & Wilk 1965) and Kolmogorov-Smirnov (Lilliefors) where sample sizes are above $n =50$ (Lilliefors 1967); a distribution was considered non normal when SW or K-S (Lilliefors) were significant at the $a < 0.05$ level. Normal distribution was also visually assessed using normal probability (Q-Q) plots generated by the SPSS 6.1.1 EXPLORE function. Bivariate outliers were detected using scatterplots and multivariate outliers were detected using a Mahalanobis outlier distance plot generated by JMP's "Correlations of Y" function (SAS Institute Inc. 1997) that graphically shows the distance of each point from the multivariate mean (centroid). Extreme multivariate outliers can be identified by their large distance values (Figure 5.3).

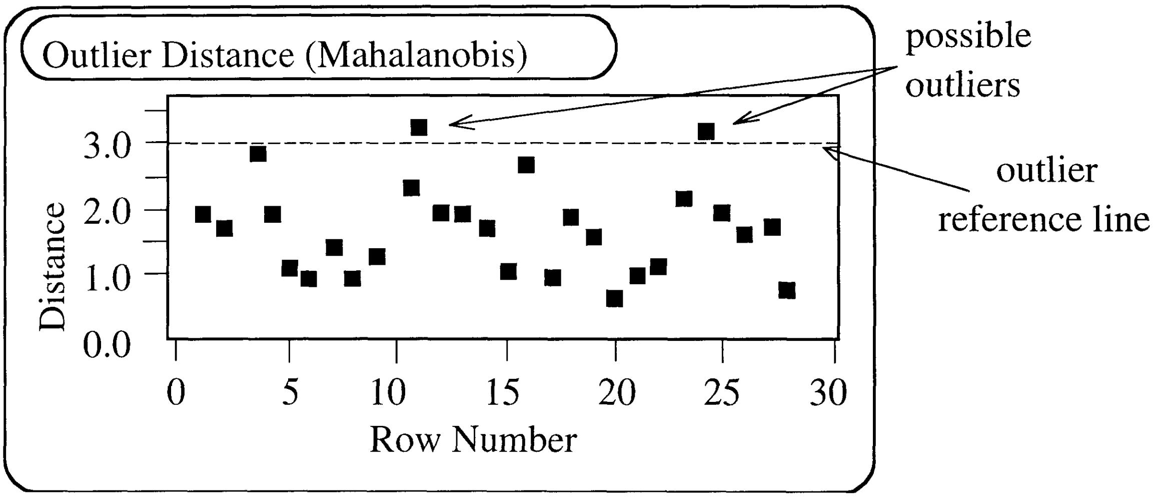


Figure 5.3: Multivariate outliers using Mahalanobis D^2

The descriptive statistics (mean, standard deviation and standard error of the mean) for all samples to be used in this analysis were generated by SPSS (Version 6.1.1 SPSS Inc. 1995, User's Guide 1993) and JMP Statistical Software (Version 3.2.1, SAS Institute Inc. 1997, User's Guide 1995) using standard formulae.

5.5.2.2 Testing for differences between groups and between sexes

As outlined in Chapter 1, a partial aim of this thesis is to assess the degree of homo- or heterogeneity of the Aboriginal populations measured by Birdsell. To assess the differences between the sample means of the 57 male and 45 female groups, one way ANOVA and the associated F ratios were used to test the significance of the between-group differences for each variable.

The degree of sexual dimorphism for each variable was assessed through the use of *Student's t*-test.

5.5.2.3 Bivariate Correlation and Regression

The relationships between variables was determined through the examination of bivariate scatterplots and the use of Pearson's correlation coefficient, *r*, Spearman's Rank Correlation Coefficient, *Rho* (ρ), and least-squares regression analysis. Correlation coefficients measure the amount of covariance between two variables (Devore and Peck, 1986) and describe the degree and direction of association between them. Where variables do not share variance the data points appear randomly distributed in a scatterplot and *r*, or *Rho*, are small and do not significantly differ from zero in a significance test. Where variables do share variance, a definite pattern of association can be detected in a scatterplot and *r* and *Rho* are significant. It is important in multivariate analyses that the relationship between variables is a linear one. As the coefficients *r* and *Rho* are not measures of linearity, scatterplots were examined to assess the linearity of the association between variables.

Pearson's *r* (parametric) and Spearman's *Rho* (non-parametric) were both calculated due to the non-normality of many of the climate variables. Whilst most of the climate variables have non-normal distributions, Annual Rainfall was extremely non-normal, to the point of there being no transformation able to bring it even close to normality. This is a function of both the climate of Australia, in which well over half of the continent has less than 400mm of rain annually, and of Birdsell's samples being mostly taken from arid areas. Given this, it has to be admitted that the product-moment correlations might be inflated or deflated from their real values.

In this analysis, where both *r* and *Rho* provide a similar result, the relationship between variables is deemed to be robust. Where there is disagreement between the results, a measure of the inflation or deflation caused by non-normal distribution and/or outliers can be assessed. Despite its extreme non-normal distribution, Annual Rainfall will be retained for, as will be seen later in the analysis, it may be a highly important environmental factor associated with geographic variation in body size, particularly in the arid west of the continent.

Although the climate variables were all non-normal to some extent, I felt that the degree of transformation required to bring them into normality may obscure the very relationships I wished to examine (Jungers et al. 1995; Reyment 1971). As a result, the use of parametric and non-parametric coefficients using untransformed measurements was considered to be adequate to assess the true relationships between variables.

5.5.2.4 Partial Correlation

Partial correlation has been used in a number of ecogeographic studies (see above) and is generally performed where the effect of intercorrelated variables needs to be examined.

In partial correlation it is of interest to measure the co-variance between two variables (eg. X and Y) with the co-variance of other (one or more) variables removed (eg. Z). The partial correlation will be the correlation between the residuals from the regression lines between X and Z, and Y and Z (Thorndike 1978: 130-131). In the case of Birdsell's Australian sample, correlations were calculated between morphological and climate variables with age, weight and stature kept constant. The co-correlates were selected to screen out the possible biasing effects of differences in age and weight between Birdsell's sample groups. Stature was also selected to assess the degree to which correlations were effected by differences in overall body size.

All partial correlations were generated with SPSS's CORRELATE: partial function (SPSS Inc., 1995, Version 6.1.1).

5.5.2.5 Multiple Correlation and Regression

Also of interest in ecogeographic studies has been the identification of the primary selective agent in climatic adaptation. In order to test this in the present analysis, stepwise multiple regression will be used.

This technique, which is a type of multiple regression, explores the relationship between a single dependant variable (DV) and multiple independent variables (IVs). It is of particular use when the independent variables are themselves correlated and the researcher is uncertain as to which IV is the most important predictor. In stepwise regression, IVs are entered sequentially into the analysis based on the criteria of a significant contribution to the regression equation leading the largest possible *r* squared value. There are no theoretical considerations behind the order of entry of variables. As in any analysis based on parametric correlation, the assumptions of normality, linearity, homoscedasticity and multicolinearity apply (Tabachnick & Fidell, 1996:132-139). Another important criterion is the ratio of cases to IVs. For stepwise multiple regression, Tabachnick and Fidell (1996: 133) suggest a case to IV ratio of 40 to 1. With Birdsell's Australians, when using the mean values of the 57 male and 45 female groups as cases testing against more than one IV (climate variables), the sample sizes are clearly deficient. This problem might be solved by using the database containing the observations on individuals, but this is also problematical, as it includes the within group variance, which would tend to obscure the between group differences in adaptation. The most common use of this method is in finding the most useful set of independent predictors for a given dependant variable (Tabachnick & Fidell 1996; Thorndike 1978). In this analysis it will be used primarily as an exploratory tool and not as predictive one. The author felt that the non-normality of the climate variables and the low ratio of cases to independent variables made it unlikely this technique would produce results of predictive value.

For this analysis the stepwise procedure was generated with JMP's Fit Model X by Y function (SAS Institute Inc., 1997), with forward entry of variables and a conservative entry level of p = 0.05. Although a liberal entry criterion has been recommended by Bendel and Afifi (1977), so as not to eliminate important variables, it was found in this case not to be beneficial, as only the major and significant proportions of shared variance needed to be identified.

5.5.2.6 Principal Components Analysis

In this study, principal component analysis (PCA) will be used to explore whether there are underlying factors of somatic and cranio-facial size and shape that co-vary with climate and may explain, or at least summarise, the correlations seen in the raw anthropometric variables.

PCA is a mathematical technique that is used to explore the relationship of variables in multivariate space in order to estimate the number of latent factors (components) that might underlie a data set. It is an exploratory technique which summarises correlations between variables, reduces a large data set to a smaller number of variables and can be used to generate hypotheses about relationships within the reduced data set (Tabachnick & Fidell, 1996: 635-637).

Mathematically, PCA produces several linear combinations of observed variables called components. The first extracted principal component is the linear combination of observed variables that maximally separates cases by maximising the variance of their component scores. The second and subsequent components are formed from the variability remaining in the data set after the variance associated with the first component is removed and all are uncorrelated (orthogonal) to each other (Tabachnick & Fidell, 1996: 664). Thus the first PC extracts the most variance and the last PC the least. If all components are retained they will exactly reproduce the correlation matrix. It is usual, however, to select only a subset of the factors for rotation and interpretation. PCA is related to factor analysis (FA), however, the important difference between them lies in the variance that is analysed. In PCA all variance is considered relevant to the solution, whereas in FA only co-variance is considered, with error and unique variance disregarded (Tabachnick & Fidell 1996: 663). Note that the terms "principal component" and "factor" may be used interchangeably below even though they are slightly different. All calculations were performed with SPSS 6.1.1 FACTOR function.

PCA's application to biometric studies

PCA, and FA, have been used extensively in the study of human behaviour (Brown 1973; Tabachnick and Fidell 1996) but its application to problems in the field of physical anthropology has only recently become more common (Brown 1973; Reyment *et al.* 1984; van Vark & Howells 1984). There are, however, a number of problems with its application to anthropometric and osteometric data. Some of these problems concern the nature of the data themselves and others, the way the data are analysed. Robert Corruccini raised concerns regarding the use of osteometric data in multivariate analyses (in this case generalised distance analysis) in 1975. He noted that many of the statistical assumptions that needed to be observed prior to a multivariate analysis (multivariate normality, linearity, homogeneity of covariance) were at best only paid lip service to, and at worst ignored by researchers using these techniques (Corruccini 1975). He argued that statistical and biological classification are different in their basic aims and assumptions (Corruccini 1975: 1) and warned against the uncritical application of multivariate techniques to data that were not inherently suitable for them (Corruccini 1975: 14).

As PCA summarises correlations between variables, it is sensitive to the effects of spurious and topographical correlation and therefore, the original selection of variables is extremely important (Brown 1973; Solow 1966). In morphometric data some variables are spuriously correlated because they cover the same anatomical region, or are topographically correlated because they share a common reference point. These correlations would not, therefore, represent true shape variability in a data set and would bias the component solution. Careful selection of variables can overcome this problem to a certain extent, however, it may not always be practically possible to eliminate such correlations altogether (Brown, 1973).

Another consideration in using PCA is: what exactly is the source of the variability being measured? In particular, a number of researchers have examined the way in which differences in size, rather than in shape contribute to the variability of a data set (Gelvin 1983; Hardy & van Gervan 1976; Howells 1957). Gelvin (1983), for instance, found that between 66% and 94% of between-groups variance was due to size alone. It is generally stated that the first principal component is a measure of a size variation in the data set, especially where all the loadings are positive (van Vark and Howells 1984; Reyment *et al.* 1984; Mizoguchi 1991).

In order to overcome the effect of size (allometry) in multivariate analyses in general, several methods have been devised (Jungers *et al.* 1995). These include methods which transform data prior to analysis: simple ratios (Howells 1969), standardising variables (Mosimann & James 1979; Penrose 1954), log transforms (Healy & Tanner 1981), double centring the data (Corruccini 1975), or the manipulation of data in a multistage analysis: for instance residual analysis or the removal of the first principal component (Hartman 1988; Reist 1985; Rohlf 1967).

In the first part of this analysis no correction for size will be undertaken as adaptation in body size is one of the objects under study, however in order to assess the relative importance of adaptations in size and in shape, size corrected variables will be examined. The method of size correction will follow that of Mosimann and James (1979), where each variable is standardised using the geometric mean of all variables. This method has been found to best assess the intrinsic shape of an individual, however it is not without its problems (see Jungers *et al.* 1995).

Other problems with PCA are methodological in nature. These include the type of matrix used to extract components or factors. Howells, for instance, stated that the total correlation matrix was not suitable to extract factors from in biological studies because it includes the effects of population differences (Howells 1973: 121). He advised the use of the pooled with-in groups correlation matrix, believing that this better represented the pooled covariation of the individuals of a number of populations (Howells 1973: 121). However, it has also been asserted that in order for the relative importance of size and shape to be assessed through a comparison of eigenvalues, the principal components should be extracted from a variance-covariance matrix (Darroch & Mosimann 1985; James & McCulloch 1990; Holliday 1997b: 431). However in this study such a comparison will not be made, as it is the variance shared by the component scores with climate variables that will be used to assess the importance of size and shape. Therefore the principal components will be extracted from a standard correlation matrix.

Procedure for conducting a PCA

The procedure for conducting a PCA was taken from Tabachnick and Fidell (1996: 635-707). As with multiple regression the data (and its resulting matrix) have to be examined for factors which may bias the result, such as the choice of variables, adequate sample size, outliers, normality, linearity, multicolinearity, homoscedasticity and singularity.

PCA is considered robust to violations of normality and linearity, however the solution is enhanced when normality and linearity are achieved, and these assumptions should be met when statistical inference is to be used (Tabachnick and Fidell 1996: 640-641). These assumptions were examined in the anthropometric data prior to analysis and there were minor violations in some variables, but these were not considered serious enough to affect the PCA solution. The climate data were unsuitable for PCA. As to adequate sample size, Tabachnick and Fidell (1996: 640) state that a minimum of 150 cases is required, although 300 is a better sample size. In the case of Birdsell's Australians, the sample sizes of the group areas (n=57 male and n= 45 female) are clearly inadequate. As a result, the components were extracted from the full set of individuals (n= 1424 male and n = 880 female) and the means of the component scores for each sample group were used in subsequent analyses.

The most critical part of PCA is the selection of the number of factors to be extracted. This number depends on the research questions being asked. Tabachnick and Fidell suggest that only factors with eigenvalues over 1 should be extracted, as they contribute the majority of variance to the factor solution (Tabachnick & Fidell 1996: 672). Howells, however, suggests that all factors should be extracted and examined (Howells, 1973b).

Following extraction, rotation is a common procedure to enhance interpretation, however, again, its use depends on both theoretical and methodological criteria. For instance, with rotation, the first principal component often loses its "size" factor (ie. not all loadings are large and positive). There are two main types of rotation. The first is orthogonal, in which, as the name suggests, the components are assumed to be uncorrelated. The second type is oblique, in which it is assumed that the components are themselves intercorrelated. Orthogonal rotation has the advantage of being easier to interpret than an oblique rotation, but the researcher has to be confident that the components are, in reality, unlikely to be correlated (Tabachnick & Fidell, 1996: 666).

Missing Data

The PCA procedure requires that there are no missing data. In the Birdsell's database some measurements were not taken when the relevant anthropometric points were missing, or were unable to be located accurately. The variables most likely to be missing in the data set are those relating to facial or mandibular height, due to the loss of the central incisors.

There are two main methods of overcoming the problem of missing data.

1. *Deletion*: to delete the cases that have missing variables. The disadvantage of this is that this acts to reduce the overall variability of the data set. Another method is to delete variables with a high number of missing values. This is not appropriate in all data sets, especially where missing values are scattered over a number of variables (Tabachnick & Fidell 1996: 640).

2. *Estimation*: to estimate the missing value. There are two main methods. The first is to replace the missing value with the mean value for the variable. This can act, however, to alter variance which can then affect subsequent correlations. Another method involves estimating the value through regression analysis, the main disadvantage of this is a tendency to overfit the data. Tabachnick and Fidell (1996: 640) note that this method can only be used on large sample sizes.

In this analysis it was felt that value estimation using the mean of the variable was the best option, as deletion of cases would have in fact seen the elimination of entire groups for some variables. In most variables there were relatively few missing cases and the substitution of the mean value was unlikely to have a great effect on their variance. This may not be the case for the facial height measurements, where many more cases were missing, however it was felt that the benefits of mean substitution outweighed the loss of variance and the problems this might cause the PCA.

5.5.3 Sources of Error in the Data Set

There a number of ways error can occur in a data set. This error can be either systematic or random in nature. Sources of error include:

1. **Intra-observer error:** anthropometrists are not robots and neither are their subjects. Even a highly skilled practitioner will rarely be able to produce exactly the same result when measuring an object more than once, and when a living individual is the object, the likelihood of error will increase. Error can occur where an anthropometric or osteometric landmark is poorly defined or difficult to locate, particularly when the point is overlaid be thick tissue. Fatigue can play a part, with the observer becoming less careful and losing concentration as fatigue sets in. Time is also a factor, especially where access to subjects is limited and the work has to be completed in a set period of time.

2. **Inter-observer error:** every observer will have their own slightly different measurement technique that can lead to variations in measurements being taken on the same sample. This can occur even when the observers have been trained identically and are using the same instruments and techniques. This can result from individual interpretations of technique, for instance, even though a measurement or point might be defined it may not be interpreted the same way by each observer (Howells, 1973b). Other problems stem from the poor reporting of methodology in some studies and by a lack of standardisation of technical terms. A perusal of any technical manual of anthropometry will serve as an illustration of the confusion over standard terms for measurements (Knussmann, 1988). In the present study this is of particular note in the analysis of the world sample, as a great many different observers are involved and their methodologies are not always available.

3. **Instrument error:** instrument incorrectly calibrated.

4. **Instrument precision:** the limitation of the scale of measurement of the instrument (eg. can it be read to the nearest metre, centimetre, millimetre or below as with digital devices.)

5. **Reading and recording error:** it is possible to misread a scale particularly when fatigued. Errors in recording observations and/or entering them onto a computer are also possible.

5.5.3.1 Reliability Analysis

While published studies into the reliability of biometrical measurement techniques have appeared from time to time, the literature is by no means extensive and much of the data appears to be contained in unpublished theses (see Lohman *et al.*, 1991). There are, in fact, no internationally accepted, standard reliability measures available (Cameron 1986).

The degree of observer error can be estimated through test-retest studies. Although methodologies vary (see Cameron, 1986: 30-36 and Utermohle *et al.*, 1983 for reviews), one of the most common procedures involves measuring a sample of objects (be they living individuals or skeletal elements) more than once over a period of time using a single observer (intra-observer error) or multiple observers (inter-observer error) and calculating the technical error of measurement (TEM), which is also sometimes referred to as the method error statistic (Cameron 1986; Dahlberg 1940; Townsend & Brown 1979 Utermohle *et al.* 1983). The TEM is defined as "an attempt to quantify the inherent imprecision of a single observation of a variable as determined by duplicate measurements of that variable" (Utermohle *et al.*, 1983: 92).

The effect of these errors on a data set can be quite extreme. Utermohle and Zegura (Utermohle & Zegura 1982) found that in an intra-observer study of human crania, 33% of variables exhibited poor repeatability, whereas in their inter-observer study this was increased to an alarming 70% variables. They concluded that a repeatability analysis should be an important baseline for the interpretation of the biological significance of their results (Utermohle & Zegura, 1982: 309). Of more concern were the results of Utermohle *et al.*'s 1983 study in which it was found that small variations in technique between observers can result in almost complete statistical discrimination between identical samples measured by different observers (1983: 86-88).

The common finding of both intra- and inter-observer studies is that certain anthropometric measurements are less reliable than others and further, that data taken on female subjects is less reliable than those on male subjects, due mainly to differences in subcutaneous fat (Bennett & Osborne 1986). Gavan (1950) listed variables of high, medium and low consistency. He found that measurements with high consistency had landmarks that were determined by the measurement: examples of this are Head Breadth or Bizygomatic diameter; or where only one landmark had a definite location, for instance Head Length. Variables with medium consistency tended to have both landmarks at defined points (eg. Bi-iliac, Bigonial diameter) and low consistency variables had either poorly defined landmarks or were themselves defined by other measurements (Gavan, 1950: 422). Measurements that were commonly repeated, and a maximum or mean value taken, also tended to be more accurate (Gavan 1950: 423). Using different methods Jamison and Zegura (1974) found that variables with set landmarks were the most repeatable in inter-observer trials.

The outcome of all these studies is that care should be taken when using measurements that have a high degree of measurement error and that researchers should take extreme caution when using data obtained by different observers, even when their methodology is fully documented. The ideal situation would be to use measurements of high reliability measured by single observer, in order to reduce the amount of error in statistical analyses.

During the course of his first expedition to Australia, Birdsell did attempt a reliability estimate of his own measurement technique, measuring a single female subject twenty-one times over eleven months. Also, as can be seen in Table 5.8, weight (n=11) and calf circumference (n=20) were not measured on every occasion.

TEM refers to the technical error of measurement, calculated from the formula of Dahlberg (1940: 125-126). CV* is the coefficient of variation calculated from the TEM and is thus different from the conventional coefficient of variation (Johnston *et al.* 1972).

TEM = $\sqrt{\frac{\sum d^2}{2N}}$ where $\sum d^2$ represents the sum of the squared differences (deviations) between the initial observation and all following observations and N is the number of paired observations.

CV* = $\frac{TEM}{\overline{X}}$ where $\overline{X}$ is the mean of all observations.

In order to assess reliability the CV* statistic is used as it is dimensionless. From this analysis the variables with the highest reliability (CV* < 1) include: Head Length, Bizygomatic Diameter, Head Breadth, Stature, Sitting Height, Humerus Length, Bigonial Diameter, Nose Breadth and Head Height, and the indices Cranial Module, Cephalic Index, Cephalo-Facial Index, Relative Sitting Height, Humerus-Sitting Height Index and Intermembral Index. Variables with the lowest reliability (CV* > 2) include: Upper Facial Height, Nose Depth, Calf Circumference, Bi-iliac Diameter, Nose Height, and Weight, and the indices Radius-Sitting Height Index, Femur-Sitting Height Index, Tibial-Femoral Index, Nasal Depth Index, Surface Area/Weight Ratio, Relative Pelvic Breadth, Calf/Tibial Index, and Nasal Breadth Index. Head Length and Cranial Module were found to be the most reliable and Weight and Nasal Index Breadth were the least reliable. This is purely an arbitrary division into high and low reliability variables, however they do generally concur with those of other studies. Although it is well known that weight is extremely labile, the fact that it was only measured in approximately half of the trials, makes its identification as a measurement of low reliability somewhat less secure.

Table 5.7 Analysis of the reliability of anthropometric measurements and indices

Variable	N	$\bar{X}$	SD	SE Mean	CV	Min	Max	TEM kg/mm	CV*
Weight	11	56.61	1.45	0.44	2.55	54.88	59.41	2.317	4.093
Stature	21	1642.10	7.01	1.53	0.43	1620	1650	5.443	0.331
Hum L	21	296.52	2.68	0.58	0.90	290	304	1.924	0.649
Rad L	21	243.10	3.67	0.80	1.51	232	248	4.514	1.857
Fem L	21	435.76	7.38	1.61	1.69	410	445	8.219	1.886
Tib L	21	359.62	5.24	1.14	1.46	349	369	3.732	1.038
Biac	21	365.00	4.29	0.94	1.18	357	373	4.195	1.149
Bi-iliac	21	285.76	3.08	0.67	1.08	282	295	7.039	2.463
Sit H	21	861.90	5.14	1.12	0.60	847	869	4.690	0.544
Calf C	20	332.95	5.26	1.18	1.58	325	343	8.184	2.458
Head L	21	186.14	0.36	0.08	0.19	186	187	0.274	0.147
Head B	21	143.90	0.54	0.12	0.37	142	145	0.387	0.269
Head H	21	119.86	1.11	0.24	0.92	117	122	1.140	0.951
Min Front D	21	100.14	0.73	0.16	0.73	99	102	1.440	1.438
Bizyg	21	125.10	0.30	0.07	0.24	125	126	0.224	0.179
Bigon	21	89.52	0.93	0.20	1.04	88	91	0.758	0.847
Tot Fac H	21	116.14	1.35	0.30	1.16	114	119	1.823	1.570
Upp Fac H	21	71.67	1.93	0.42	2.70	66	74	1.449	2.022
Nose H	21	60.57	1.75	0.38	2.89	57	63	2.236	3.692
Nose B	21	33.17	0.37	0.08	1.10	33	34	0.285	0.859
Nose D	21	29.57	0.81	0.18	2.74	28	32	0.707	2.391
Mand D	21	37.29	0.72	0.16	1.92	36	39	0.548	1.469
SA	11	16145.66	163.39	49.26	1.01	15954.95	16437.20	245.137	1.518
SA/M	11	285.33	4.39	1.32	1.54	276.67	290.75	7.130	2.499
RPB	21	0.17	0.0023	0.0005	1.32	0.17	0.18	0.005	2.651
RShB	21	22.23	0.26	0.06	1.15	21.76	22.70	0.275	1.237
RSitH	21	52.49	0.41	0.09	0.79	51.33	53.21	0.386	0.735
PI	11	42.85	0.42	0.13	0.98	42.00	43.37	0.696	1.624
Calf/Tib	20	92.73	2.14	0.48	2.31	90.16	98.28	2.545	2.745
Rad/Hum	21	81.98	1.15	0.25	1.40	78.91	83.33	1.566	1.911
Tib/Fem	21	82.56	2.13	0.46	2.58	79.32	88.78	1.866	2.260
Interm	21	67.85	0.78	0.17	1.15	65.67	69.77	0.574	0.845
Fem/Sit H	21	50.56	0.80	0.17	1.57	47.90	51.50	1.067	2.110
Tib/Sit H	21	41.73	0.76	0.17	1.83	40.35	43.57	0.575	1.378
Hum/Sit H	21	34.40	0.36	0.08	1.06	33.53	35.27	0.270	0.784
Rad/Sit H	21	28.20	0.38	0.08	1.35	27.39	28.77	0.588	2.085
NIB	21	54.80	1.58	0.35	2.89	52.38	57.89	1.888	3.446
NID	21	89.17	2.71	0.59	3.04	83.58	96.97	2.130	2.389
CI	21	77.31	0.28	0.06	0.36	76.34	77.54	0.212	0.275
CM	21	149.97	0.33	0.07	0.22	149.33	150.67	0.354	0.236
CFI	21	86.93	0.38	0.08	0.43	86.21	88.03	0.282	0.325
TFI	21	92.84	1.11	0.24	1.20	91.20	95.20	1.427	1.537

SECTION IV

ANALYSIS

CHAPTER 6

RESULTS PART 1:

EXPLORATORY AND DESCRIPTIVE STATISTICS

6.1 INTRODUCTION

The results of this analysis will be reported in Chapters 6 through 9. The first section of Chapter 6 covers the descriptive and exploratory phase of the data analysis. The second section examines evidence for secular change in the population groups sampled in both of Birdsell's two expeditions. The third section of this chapter examines group differences using analysis of variance (ANOVA). Chapter 7 reports the results of the bivariate and multivariate correlation analyses between climate and human morphology in Birdsell's Australians. The results of the principal components analyses will be presented in Chapter 8, and finally in Chapter 9, bivariate correlations based on the world sample collected for this study will be reported.

6.2 EXPLORATORY STATISTICS

This section deals with the screening of the database wherein the data were examined for error, outliers and normal distribution. This procedure is vital, as the majority of the statistical techniques to be used in this analysis are sensitive to violations of normal distribution, homogeneity of variance and the presence of outliers. The screening methodology was outlined in Chapter 5, Section 5.5.2.1.

Other issues of importance to the integrity of parametric statistical analysis, such as bivariate and multivariate normality, heterodasticity and linearity will be discussed in later chapters where appropriate.

6.2.1 Screening of anthropometric measurements and ratios

A number of extreme outliers were identified, and if confirmed to be errors, either corrected or excluded from further analysis. Most of the outliers had been identified by Birdsell as incorrect and so noted on the original data sheets.

The compliance of distributions with the normal curve was assessed through the SPSS Explore function, with the examination of plots (frequency histograms, box plots and Quantile-Quantile plots) and the calculation of test statistics. The test statistics used, included Shapiro-Wilk (1965) for samples ≤ 50 (the vast majority of samples), and Kolmogorov-Smirnov (with a Lilliefors significance test) where sample sizes were < 50 (Lilliefors 1967). The significance level was set at $a < 0.05$.

As mentioned in Chapter 4, Birdsell collected the measurements of 1424 male and 880 female individuals of unmixed Aboriginal ancestry. These were divided in 57 male and 45 female groups based on tribal or culture-area affiliation. In the Tables 6.1 - 6.4, below, the column entitled "Full sample distribution" includes the test statistic and significance level for each variable using the full sample of individuals. These distributions have been reported as the full sample is used to produce the correlations matrices for the extraction of principal components (see Chapter 8). The second column, "Between groups distribution", is the statistic calculated on the sample of group means for each variable. These group means were used to produce the bivariate correlations and multivariate regressions. The third column, "Within groups distributions: % non-normal", records the percentage of sample groups that exhibit significant test statistics for each variable. This column provides an indicator of the variables most likely to be non-normal.

Table 6.1: Distribution tests and significance levels for body measurements in male and female data sets.

	Full sample distribution (all individuals pooled)				Between groups distribution				Within groups distribution	
	male		female		male		female		male	female
Variable	n	KS	n	KS	n	KS/SW*	n	SW	% non-normal	
Weight	1415	.0788***	857	.1170***	57	.0431	45	.9725	22.8	22.22
Stature	1419	.0152	877	.0191	57	.0423	45	.9675	3.5	8.9
Hum L	1418	.0231	878	.0262	57	.0938	45	.8775**	12.3	2.2
Rad L	1417	.0291**	872	.0164	57	.0565	45	.9514	7.02	6.8
Fem L	1414	.0199	857	.0194	57	.1116	45	.9494	12.3	9.3
Tib L	1415	.0140	877	.0230	57	.0721	45	.9038**	7.02	9.1
Biac D	1419	.0254*	878	.0275	57	.0548	45	.9691	5.3	4.4
Bi-il D	564	.0323	161	.1140***	28	.9764	17	.9569	3.4	14.3
Sitt H	1417	.0102	871	.0225	57	.0579	45	.9667	8.8	8.9
Calf C	1404	.0363***	874	.0701***	57	.0472	45	.9507	17.5	4.6

(* Shapiro-Wilks statistics is reported for bi-iliac only in males and for all female variables.)

A complete record of results for the within groups distributions can be found in Appendix 2, along with the summary statistics for each group. It should also be noted that in the female set, the sample sizes for certain variables in a number of groups were too small to calculate the statistical tests for the within groups distributions.

In the "full-sample" of individuals most body measurements are normally distributed, the exceptions being weight, radius length, biacromial diameter and calf circumference in males, and weight, bi-iliac diameter and calf circumference in females. Of all the variables, weight was found to be the most non-normal. In the "full-sample" sets, it is significantly non-normal for both males and females and also shows the highest percentage (22%) of "within group" samples with non-normal distributions. Plots generated by SPSS (not included here) indicate that the distributions for weight tend to be positively skewed. The same situation applies to calf circumference, which is highly correlated with weight (see Tables 7.3 and 7.4). The cause of this positive skew is difficult to pin down. In males it does not appear to be related to age. There is no correlation between weight and age in males (Table 7.2), and a subset obese males (BMI > 30) has an average age only 3 years above that the entire sample. However, this same subset reveals that most of the obese males come from the western half of the continent, where European colonisation, and thus the introduction of high calorie foodstuffs, was the most recent. The situation for females is slightly different, with significant correlations between age and weight occurring (Table 7.2), however again, the majority of obese individuals are from the west of Australia. It is possible that this skew may be due to the influence of these introduced foods and this issue is pursued further below.

The skew in weight may partially explain the non-normal distribution in bi-iliac breadth in females, as weight and bi-iliac breadth are highly correlated (Table 7.2), but it cannot be the only factor involved, as male bi-iliac breadth is normally distributed. The positive skew seen in females indicates that there are more females than might be predicted with broad ilia in the sample. Age distributions of the samples indicate that there are proportionately fewer females over 40 than males. It is possible that the difference is due to obstetric selection, as females with a broader pelvis might be more likely to survive to reach old age, but this is merely speculative.

For the "between groups" sets, all body variables are normally distributed in the male sample and in the females, only humerus length and tibia length are non-normal. An examination of the distributions for humerus and tibia length in males and females, indicates that this non-normality (due to a positive skew) is the result of sampling differences between the sexes. For the "within groups" distributions there are consistently high percentages (over 5%) of non-normal groups for the variables of weight, radius, femur and tibia lengths and sitting height in both the male and female samples. However, for other variables, the percentages vary between the sexes. In some cases the differences are slight, however for the male groups, the variables of humerus length and calf circumference exhibit more non-normal distributions than among female groups which, in turn, have more non-normal distributions for bi-iliac diameter than do the males. The meaning of these differences is obscure and they may simply be random effects due to sampling: certainly sample sizes vary quite widely between groups and between males and female sets in each sample area.

For ratios based on body measurements, in the full set of individuals, surface area and tibia length/femur length ratio are found to be non-normal in males, and surface area, surface area to weight ratio, relative pelvic breadth, ponderal index, calf circumference/tibia length index are non-normal in females. In the "between groups" sets, there are no non-normal distributions in the male sample, but in females, relative pelvic breadth, calf circumference/tibia length index, intermembral index, tibia length/sitting height index and humerus length/sitting height index are all statistically non-normal.

Table 6.2: Distribution tests and significance levels for body indices in male and female samples.

	Full sample distribution				**Between groups distribution**				**Within groups distribution**	
	male		**female**		**male**		**female**		**male**	**female**
Variable	**n**	**KS**	**n**	**KS**	**n**	**KS/SW***	**n**	**SW**	**% non-normal**	
SA	1413	**.0470*****	854	**.0619*****	57	.0680	45	.9883	7.02	6.7
SA/W	1413	.0240	854	**.0581*****	57	.0611	45	.9709	10.5	8.9
RPB	563	.0376	160	**.1102*****	28	.9254	17	.8520*	3.6	0
RSB	1416	.0162	875	.0266	57	.0618	45	.9785	8.8	8.9
R Sit H	1414	.0183	871	.0293	57	.0649	45	.9478	3.5	6.7
PI	1413	.0218	854	**.0427*****	57	.0833	45	.9883	8.8	11.1
Calf/Tib	1400	.0215	873	**.0679*****	57	.0582	45	**.9413***	10.5	11.6
Rad/Hum	1415	.0235	872	.0243	57	.0787	45	.9624	3.5	9.1
Tib/Fem	1411	**.0379*****	857	.0281	57	.0695	45	.9633	17.5	4.7
Interm	1404	.0193	850	.0291	57	.0588	45	**.9310***	7.02	14.3
Fem/Sit	1408	.0181	848	.0191	57	.0869	45	.9586	1.8	11.6
Tib/Sit	1409	.0152	868	.0219	57	.0720	45	**.8729****	3.5	6.8
Hum/Sit	1412	.0176	869	.0287	57	.0815	45	**.8731****	5.3	4.4
Rad/Sit	1411	.0217	863	.0168	57	.0623	45	.9562	8.8	4.6

(* Shapiro-Wilks statistics is reported for relative pelvic breadth (RPB) only in males and for all female variables.)

In the "within groups" distributions, consistently high percentages of non-normal distributions (over 5% in both male and female groups) are evident for the variables of surface area, surface area to weight ratio, relative shoulder breadth, ponderal index, calf circumference/tibia length index and intermembral index. Percentages of non-normal distributions were greater in males than in females in tibia length/femur length ratio in males over females, and in intermembral index, radius length/humerus length ratio, and greater in females compared to males in femur length/sitting height ratio. Interestingly, whereas both the "full-sample" and "between groups" distributions for relative pelvic breadth in females are non-normal, there were no sample groups (within-groups) that exhibited a non-normal distribution for this variable.

In the male and female "full-sample" sets of cranio-facial measurements, all variables produced test statistics indicating non-normal distributions. In contrast, in the "between groups" sets, only head height was non-normal in males, and bigonial breadth non-normal in females. In order to more fully explore the distributions, the histograms, box plots and Q-Q plots generated by SPSS were examined. These seemed to suggest that the KS (Lilliefors) test was, in some cases, too sensitive, particularly where the statistic was low. For example, the normality statistics for head length indicated a significant departure from normal distribution, whereas the plots suggested an approximately normal distribution (see Figure 6.1 below). In most cases, however, the plots confirmed the statistics. The source of the non-normality in the full-set of individuals would appear to be uneven sampling with a greater number of individuals sampled in the northwest compared to other areas in Australia. As well, an examination of frequency histograms hints at bi- or multi-modality in many of the cranio-facial variables, however again, this may simply be the result of uneven sampling.

Table 6.3: Distribution tests and significance levels for head and face measurements in male and female data sets

	Full sample distribution				Between groups distribution				Within groups distribution	
	male		female		male		female		male	female
Variable	**n**	**KS**	**n**	**KS**	**n**	**KS**	**n**	**SW***	**% non-normal (n)**	
Head L	1423	**.0352*****	879	**.0417*****	57	.0919	45	.9779	7.02	6.7
Head B	1423	**.0536*****	880	**.0535*****	57	.0634	45	.9716	7.02	4.4
Head H	1422	**.0417*****	880	**.0493*****	57	**.1250***	45	.9688	10.5	8.9
Min Fr D	1423	**.0612*****	878	**.0585*****	57	.0703	45	.9647	15.8	6.7
Bizyg	1424	**.0505*****	879	**.0746*****	57	.0523	45	.9822	8.8	11.4
Bigon	1421	**.0362*****	880	**.0793*****	57	.0822	45	**.9440***	3.5	8.9
TotFH	1297	**.0435*****	826	**.0565*****	57	.0661	45	.9800	5.3	4.8
UppFH	1251	**.0490*****	810	**.0666*****	57	.0500	45	.9727	15.8	2.6
Nose H	1420	**.0505*****	879	**.0795*****	57	.0659	45	.9640	8.8	2.2
Nose B	1423	**.0746*****	878	**.0802*****	57	.0581	45	.9722	10.5	17.8
Nose D	1422	**.0784*****	879	**.0971*****	57	.0642	45	.9789	22.8	8.9
Mand D	1267	**.0695*****	822	**.0747*****	57	.0777	45	.9676	12.3	19.5

(* Shapiro-Wilks statistics is reported for all female variables.)

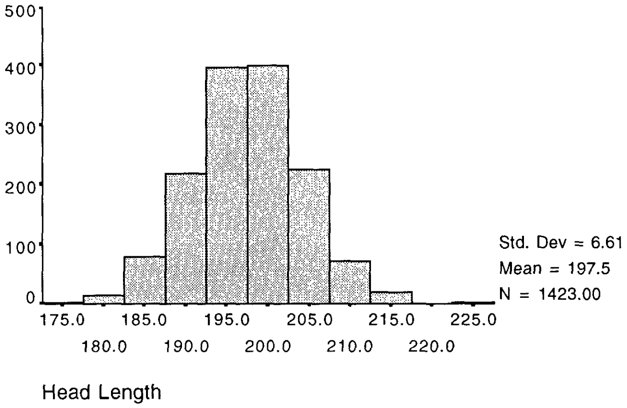
In the "within group" distributions, head length, head height, minimum frontal diameter, bizygomatic diameter, nose breadth, nose depth and mandibular depth all produced consistently high percentages of non-normal distributions in both the male and female samples. Percentages were greater in males than in females in minimum frontal diameter and upper facial height, and in females compared to males, in bigonial breadth, nose breadth and mandibular depth.

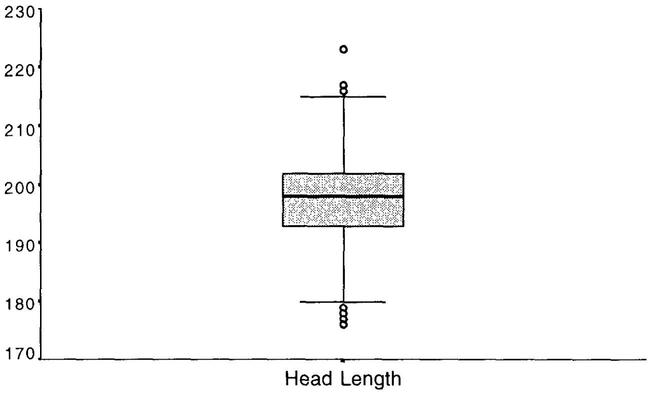
As might be expected from the distributions of the absolute measurements, the "full sample" distributions of all the ratios are non-normal, except that of Cephalic Index in females. For the "between groups" distributions only Nasal Breadth Index in males, and Total Facial Index in females are non-normal. Most of the "within group" distribution percentages are over 5% for both males and females. Major differences between sexes occur in Nasal Index (H/B) in males and Total Facial Index in females.

Overall it can be seen that when the total sample of individuals are tested, absolute measurements and indices of the head and face tend to be more non-normal than are those of the body. As for the distribution of group means, relatively few depart from normal distribution and thus there is no need for the deletion or transformation of anthropometric variables before proceeding with further analysis.

SPSS Output

```
HEAD_LGT  Head Lgth
Valid cases:    1423.0  Missing cases:    1.0  Percent missing:   .1
Mean          197.48       Std Err        .1752       Min          176.00        Skewness     .0154
Median        198.00       Variance       43.67       Max          223.00        SE Skew      .0649
5% Trim       197.4715     Std Dev        6.61        Range        47.00         Kurtosis     .0925
95% CI for Mean (197.1363, 197.8236)                  IQR9.0000                  SE Kurt      .1296
                    Statistic           df            Significance
K-S (Lilliefors)    .0352               1423          .0003
```





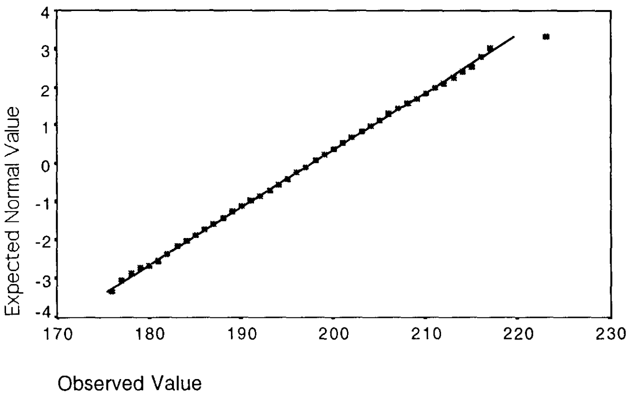


Figure 6.1: SPPS output and Histogram, Boxplot and Q-Q Plot for male head length (n = 1423) showing a significant KS (Lilliefors) statistic, but reasonable degree of normality in the associated plots.

Table 6.4: Distribution tests and significance levels for head and face ratios in male and female data sets.

	Full sample distribution				Between groups distribution				Within groups distribution	
	male		female		male		female		male	female
Variable	n	KS/SW	n	KS/SW	n	KS/SW	n	KS/SW	% non-normal	
N I (H/B)	1420	**.0712*****	877	**.0498*****	57	.0740	45	.9679	14.04	6.6
N I (D/B)	1422	**.0376*****	878	**.0435*****	57	**.1361****	45	.9603	10.5	11.11
C I	1423	**.0368*****	879	.0269	57	.0703	45	.9782	8.8	8.9
C M	1422	**.0279*****	879	**.0312***	57	.0564	45	.9497	5.3	6.7
CF I	1423	**.0432*****	879	**.0399****	57	.0471	45	.9849	8.8	6.8
TF I	1287	**.0343****	826	**.0382****	57	.0918	45	**.9255****	1.8	9.7

6.2.2 Screening of climate variables

The situation for the climate variables is quite different. The distributions tested are the "mean" values taken from as near to the centre of each sample groups' land area as possible (see Chapter 4, Figure 4.3). Several variables depart substantially from normal distribution, in particular Annual Rainfall and Relative Humidity of the Driest Month (Least Humid Month). A number of transformations were attempted, however no uniform method was found that could be applied to all variables, and Annual Rainfall, which is dramatically positively skewed defied transformation to normality. It was thus decided to leave the climate variables untransformed, but to report both parametric and non-parametric correlation coefficients to gauge the effect of the non-normal distribution on the results.

Table 6.5: Distribution tests and significance levels for the mean values of climate variables sampled in the 57 male and 45 female group areas

	Between group-area distributions			
	Male sample areas		Female sample areas	
Variable	n	KS	n	SW
Max Hot*	57	.0937	45	**.9025*****
Min Cold	57	.1133	45	**.9310***
Ann Temp Var	57	**.1323***	45	**.8479*****
Av Ann Temp	57	**.1297***	45	**.8994*****
RH Wet	57	.0869	45	.9463
RH Dry	57	**.2350*****	45	**.8106*****
Ann RH Var	57	.0876	45	.9735
Ann Rain	57	**.2728*****	45	**.7234*****

(* see Chapter 4 for full variable descriptions.)

6.3 DESCRIPTIVE STATISTICS

The descriptive statistics for all measurements and indices of the entire male (n = 1424) and female (n = 880) samples are presented in Tables 6.6 to 6.9. Also included are the *Student's t*-tests comparing the male and females means for each variable. Tables recording the descriptive statistics for sample groups are presented in Appendix 2.

Age has been included with the anthropometric variables, as many measurements of the body and face are known to vary with age. As can be seen in Table 6.6, the average age of the female sample is about five years less than that of the male sample. This difference is statistically significant, however it is unlikely that the age gap will have contributed to average differences between the anthropometric variables.

Males are significantly larger than females in all measurements of the body, except for bi-iliac breadth, where there is no significant difference between the male and female samples (Table 6.6). Therefore, in terms of body linearity, males are significantly more linear for the index of relative pelvic breadth than are females (Table 6.7). Males are also found to be more linear in the indices of ponderal index, calf/tibial, radio-humeral, tibio-femoral, humeral/sitting height and radial/sitting height. Therefore on average, males have greater overall body linearity and have longer distal limb segments and longer upper limbs relative to trunk height, than do females. Females, on the other hand, have a significantly higher surface area to weight ratio and also relatively narrower shoulders, longer legs relative to arm length and longer femurs relative to trunk height. Where males and females are similar, are in the indices of relative sitting height and tibia/sitting height.

Table 6.6: Descriptive statistics of body measurements for all individuals: males compared with females and including Student's t-tests.

Variable	Sex	N	Mean	Std Dev	Min	Max	*t* and p
Age	M	1423	40.44	14.37	18.00	85.00	
	F	879	35.45	13.97	17.00	80.00	8.18***
Weight	M	1415	61.53	11.06	35.37	134.69	
	F	857	54.03	13.94	26.30	125.17	14.17***
Stature	M	1419	1677.85	73.73	1399.00	1897.00	
	F	877	1571.31	65.87	1348.00	1815.00	35.02***
Humerus L	M	1418	332.72	18.48	261.00	384.00	
	F	878	310.81	17.96	244.00	361.00	27.90***
Radius L	M	1417	271.81	15.41	216.00	320.00	
	F	872	249.94	14.56	199.00	291.00	32.70***
Femur L	M	1414	463.66	26.10	370.00	555.00	
	F	857	440.68	24.64	306.00	525.00	20.76***
Tibia L	M	1415	396.81	25.47	311.00	485.00	
	F	877	372.73	23.58	290.00	446.00	22.62***
Biacromial	M	1419	366.58	18.45	290.00	425.00	
	F	878	331.63	19.09	268.00	394.00	43.53***
Bi-iliac	M	564	268.35	15.97	222.00	326.00	
	F	161	268.84	17.18	229.00	332.00	-0.34 ns
Sitting H	M	1417	847.74	35.76	736.00	947.00	
	F	871	795.46	33.34	707.00	918.00	34.83***
Calf Circ	M	1404	311.98	28.52	231.00	413.00	
	F	874	285.95	34.55	200.00	442.00	19.50***

(ns = not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$)

Table 6.7: Descriptive statistics of body indices for all individuals: males compared with females and including Student's t-tests.

Variable	Sex	N	Mean	Std Dev	Min	Max	*t* and p
SA	M	1413	16925.7	1615.84	11756.4	23798.9	
	F	854	15209.2	1803.15	10623.0	21970.0	23.45***
SA/W	M	1413	279.03	23.54	176.69	341.47	
	F	854	290.51	37.33	175.52	410.68	-8.98***
RPB	M	563	0.1633	0.0078	0.1400	0.1918	
	F	160	0.1774	0.0102	0.1576	0.2194	-18.76***
RShB	M	1416	21.86	0.95	18.44	25.02	
	F	875	21.12	1.07	17.73	25.21	17.25***
RSitH	M	1414	50.54	1.26	46.30	54.50	
	F	871	50.64	1.38	46.57	55.88	-1.78 ns
PI	M	1413	42.73	2.10	32.97	49.70	
	F	854	42.05	3.24	31.59	51.22	6.06***
Calf/Tib	M	1400	78.86	7.83	55.61	109.12	
	F	873	76.94	10.08	53.33	129.24	5.08***
Rad/Hum	M	1415	81.74	3.07	70.49	97.99	
	F	872	80.46	3.07	65.91	91.01	9.68***
Tib/Fem	M	1411	85.60	3.09	75.39	98.92	
	F	857	84.74	3.52	69.18	96.98	6.09***
Intermemb	M	1404	70.29	2.05	63.72	79.15	
	F	850	69.00	2.08	57.04	81.48	14.40***
Fem/Sit	M	1408	54.71	2.49	45.07	61.87	
	F	848	55.40	2.60	41.58	65.20	-6.27***
Tib/Sit	M	1409	46.82	2.42	39.42	54.16	
	F	868	46.86	2.55	39.01	54.81	-0.38 ns
Hum/Sit	M	1412	39.26	1.76	32.54	45.03	
	F	869	39.08	1.90	33.15	44.84	2.30*
Rad/Sit	M	1411	32.08	1.47	27.76	38.26	
	F	863	31.43	1.56	24.97	35.89	10.00***

(ns = not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$)

Table 6.8: Descriptive statistics of cranio-facial measurements for all individuals: males compared with females and including Student's t-tests.

Variable	Sex	N	Mean	Std Dev	Min	Max	*t* and p
Head L	M	1423	197.48	6.61	176.00	223.00	
	F	879	188.19	5.99	169.00	205.00	33.93***
Head B	M	1423	143.10	5.41	128.00	160.00	
	F	880	137.04	4.85	124.00	154.00	27.15***
Head H	M	1422	124.64	5.90	102.00	147.00	
	F	880	118.78	5.70	101.00	139.00	23.46***
Min Front D	M	1423	107.11	4.79	92.00	123.00	
	F	878	104.33	4.72	90.00	125.00	13.59***
Bizygomatic	M	1424	141.20	5.60	125.00	165.00	
	F	879	132.03	5.34	117.00	149.00	38.85***
Bigonial	M	1421	103.73	6.56	80.00	125.00	
	F	880	98.23	6.08	82.00	120.00	20.09***
Tot Facial H	M	1297	117.71	6.77	95.00	141.00	
	F	826	109.57	6.33	92.00	137.00	27.70***
Upp Facial H	M	1251	70.51	5.10	56.00	89.00	
	F	810	68.20	4.72	55.00	86.00	10.34***
Nose H	M	1420	51.39	4.14	38.00	69.00	
	F	879	49.03	3.84	36.00	64.00	13.65***
Nose B	M	1423	49.73	3.89	36.00	65.00	
	F	878	44.41	3.78	34.00	57.00	32.21***
Nose D	M	1422	31.99	2.68	21.00	43.00	
	F	879	29.20	2.46	21.00	38.00	25.03***
Mandibular D	M	1267	42.70	3.42	30.00	55.00	
	F	822	39.14	3.61	26.00	51.00	22.74***

(ns = not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$)

Table 6.9: Descriptive statistics of cranio-facial indices for all individuals: males compared with females and including Student's t-tests.

Variable	Sex	N	Mean	Std Dev	Min	Max	*t* and p
NIB	M	1420	97.37	10.62	64.29	139.47	
	F	877	91.10	10.01	65.57	130.77	14.05***
NID	M	1422	64.64	6.73	43.64	100.00	
	F	878	66.09	6.82	50.00	97.06	-4.99***
CI	M	1423	72.52	3.15	62.20	83.33	
	F	879	72.87	2.85	64.65	82.94	-2.68**
CM	M	1422	155.07	4.52	141.33	170.67	
	F	879	148.00	4.15	136.67	160.33	19.21***
CFI	M	1423	98.74	3.79	85.16	114.58	
	F	879	96.38	3.22	86.49	113.74	15.35***
TFI	M	1287	83.35	5.05	68.84	101.48	
	F	826	83.01	4.82	68.09	107.03	1.53 ns

(ns = not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$)

As might be expected, males are absolutely larger than females in all measurements of the head and face (Table 6.8). As for cranio-facial shape, females tend to have relatively narrower and more protrusive noses, smaller and somewhat less dolichocephalic heads and somewhat narrower faces relative to head breadth than do males (Table 6.9). Both males and females share similar proportions of facial height to breadth.

6.4 EVIDENCE FOR SECULAR CHANGES

Before proceeding to an examination of the statistical differences between the sample groups used in this analysis, it is pertinent to gauge the effect that the elapsed time between the first and second of Birdsell's expeditions may have had on anthropometric measurements. Fortunately, Birdsell measured three Western Desert tribes during both expeditions: the Nyanganytatjara (B5 and T11, group 36), Mandjindja (B6 and T9, group 34) and the Ngatatjara (B7 and T13, group 38). Comparison is possible between the males of all three tribes, but in only one tribe, the Nyanganytatjara, were there enough females measured in both expeditions to allow a comparison. In his 1993 monograph Birdsell outlined the differences between the earlier and later samples (Birdsell 1993: 304-416; 422-429). I have also included four tables (6.10 - 6.13) recording the descriptive statistics for each variable and the results of a *Student's t*-test between the means for the earlier and later samples.

As was pointed out by Birdsell and is clear in the tables below, the greatest differences between the earlier and later male samples occur in body weight. In the 13 to 15 years between the expeditions the average body weight of the adult males of these tribes increased between 6.27 and 9.68 kg, and these differences are all statistically significant. There was, however, little change in female body weight over the same period. Two factors that could potentially account for differences in weight in any population are average age and stature. Body-weight can change with age, but the effect varies between human populations. In European groups, for instance, body weight can increase into the seventh decade of life, yet in other groups, particularly those that are nutritionally disadvantaged, the effect is less marked or even reversed (Sinnett et al. 1973).

There is some evidence for an increase of body weight with age in Birdsell's Aboriginal male groups. For instance, in figure 6.2, that compares age classes (based on estimated age) with weight for the Njangamarda (Group 39, n = 108), there is a slight increase in average weight until the 6th decade whereafter it decreases. This tribal group was chosen, rather than one the three twice-measured groups, because of its large sample size and the fact that all individuals were measured in the second expedition.

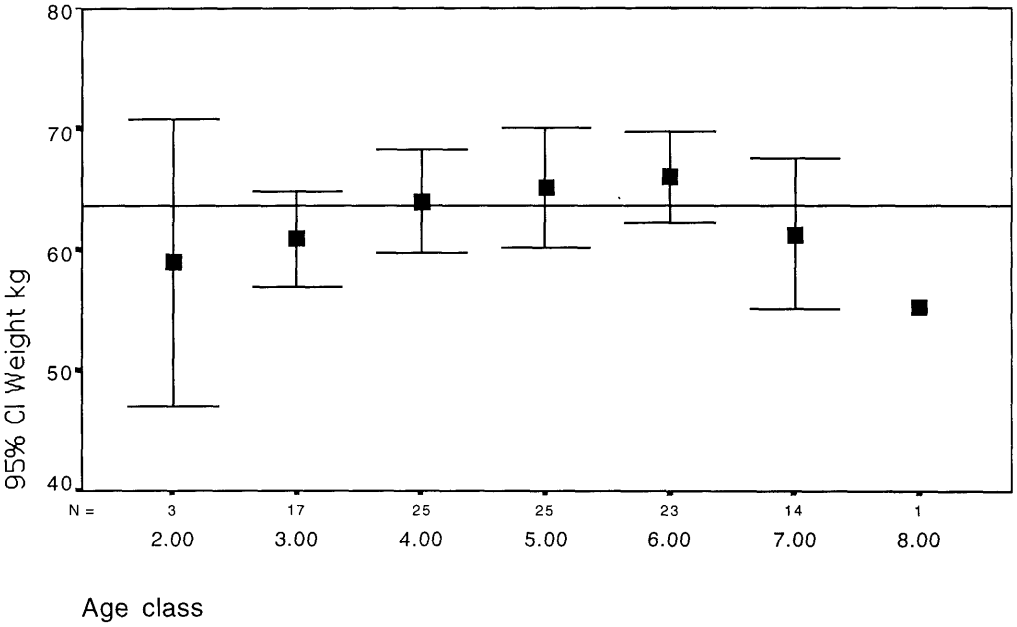


Figure 6.2: Mean weight with 95% confidence limits for age classes 2 to 8 in Njangamarda males. Age classes 2: 18-19; 3: 20-29; 4: 30-39; 5: 40-49; 6: 50-59; 7: 60-69; 8: 70-79. Reference line at total group mean.

For the three twice-measured tribal groups average ages are comparable, with only the two Nyanganytatjara groups differing significantly in age. Yet in all cases, the "earlier-measured" group is the older, and it is they who should be somewhat heavier - clearly they are not (see Table 6.10). As for stature, it increases over time in all three male groups and the single female group: the increases ranging from 0.9 cm in females and 1.3cm to 2.6cm in males. The differences, however, are statistically non-significant. Further, when weight for height plots and ratios are examined (see ponderal index and Figure 6.3) they clearly indicate the increases in stature between the earlier and later groups do not account for the increases in weight.

Table 6.10: *Student's t*-test on anthropometric variables of tribes measured in 1930s and 1950s: body measurements.

Tribe (group)	**Mean Difference B5 - T11 Nyanganytatjara (G36)**		**Mean Difference B6 - T9 Mandjindja (G34)**		**Mean Difference B7 - T13 Ngatatjara (G38)**	
	M	**F**	**M**	**F**	**M**	**F**
Age x̄ (df)	-7.06 (39)	1.92 (17)	-2.46 (44)	NA	-4.19 (39)	NA
t, p	**2.12***	0.75	0.84	NA	1.67	NA
Weight x̄ (df)	-6.27 (38)	-0.35 (16)	-7.48 (45)	NA	-9.68 (39)	NA
t, p	**-2.21***	-0.65	**-2.47***	NA	**-3.09****	NA
Stature x̄ (df)	-26.00 (39)	-9.17 (17)	-15.80 (45)	NA	-1.98 (39)	NA
t, p	-1.58	-0.31	-.881	NA	-.599	NA
Hum L x̄ (df)	-9.15 (39)	-11.34 (17)	-6.24 (45)	NA	-2.24 (39)	NA
t, p	-1.72	-1.33	-1.37	NA	-0.40	NA
Rad L x̄ (df)	-8.73 (38)	-9.88 (16)	-3.97 (45)	NA	-4.20 (39)	NA
t, p	**-2.59***	-1.35	-1.04	NA	0.91	NA
Fem L x̄ (df)	-15.64 (39)	-11.99 (16)	-7.07 (45)	NA	-1.87 (39)	NA
t, p	**-2.97****	-1.27	-1.23	NA	-0.23	NA
Tib L x̄ (df)	-10.09 (39)	-15.16 (17)	-0.89 (45)	NA	-1.56 (39)	NA
t, p	-1.91	-1.61	-0.16	NA	-0.22	NA
Biac D x̄ (df)	-9.49 (39)	0.18 (17)	1.58 (45)	NA	-5.52 (39)	NA
t, p	**-2.39***	0.03	0.33	NA	-1.16	NA
Sitt H x̄ (df)	-30.19 (39)	8.65 (17)	-21.83 (45	NA	-16.16 (38)	NA
t, p	**-2.96****	0.61	**-2.25***	NA	-1.45	NA
Calf Circ x̄ (df)	-12.37 (39)	15.22 (17)	-3.43 (45)	NA	-22.23 (39)	NA
t, p	-1.42	1.28	-0.46	NA	**-3.09****	NA

(Weight in kg, all other measurements in mm. A negative difference value indicates the later group has a larger measurement for that particular variable than the earlier group. * $p \leq 0.05$; ** $p \leq 0.01$)

Table 6.11: *Student's t*-test on anthropometric variables of tribes measured in 1930s and 1950s: body indices.

Tribe (group)	**Mean Difference B5 - T11 Nyanganytatjara (G36)**		**Mean Difference B6 - T9 Mandjindja (G34)**		**Mean Difference B7 - T13 Ngatatjara (G38)**	
	M #	**F**	**M**	**F**	**M**	**F**
SA x̄ (df)	-894.33(38)	-25.74 (16)	-952.64 (45)	NA	1210.77 (39)	NA
***t*, p**	**-2.26***	-0.03	**-2.20***	NA	**-2.53***	NA
SA /M x̄ (df)	12.22 (38)	0.10 (16)	15.42 (45)	NA	22.36 (39)	NA
***t*, p**	1.95	0.01	**2.64***	NA	**3.54****	NA
RSB x̄ (df)	-0.23 (39)	0.14 (17)	0.31 (45)	NA	-0.18 (39)	NA
***t*, p**	-0.84	0.39	1.41	NA	-0.75	NA
R Sit H x̄ (df)	-1.05 (39)	0.85 (17)	-0.84 (45)	NA	-0.59 (38)	NA
***t*, p**	**-2.55***	1.45	**-2.46***	NA	-1.64	NA
PI x̄ (df)	0.74 (38)	-0.06 (16)	1.16 (45)	NA	1.82 (39)	NA
***t*, p**	1.32	-0.05	**2.39***	NA	**3.42*****	NA
Calf/Tib x̄ (df)	-1.12 (39)	7.26 (17)	-0.66 (45)	NA	-5.33 (18)	NA
***t*, p**	-0.46	2.11	-0.31	NA	**-2.51***	NA
Rad/Hum x̄ (df)	-0.46 (38)	-0.12 (16)	0.37 (45)	NA	-0.73 (39)	NA
***t*, p**	-0.50	-0.10	0.43	NA	-0.75	NA
Tib/Fem x̄ (df)	0.70 (39)	-1.81 (16)	1.12 (45)	NA	0.03 (39)	NA
***t*, p**	0.86	-1.10	1.46	NA	0.03	NA
Interm x̄ (df)	-0.02 (38)	-0.63 (15)	-0.54 (45)	NA	-0.50 (39)	NA
***t*, p**	-0.04	-0.64	-0.84	NA	-1.00	NA
Fem/Sit x̄ (df)	0.12 (39)	-2.10 (16)	0.57 (45)	NA	0.46 (38)	NA
***t*, p**	0.17	-2.03	0.70	NA	0.59	NA
Tib/Sit x̄ (df)	0.49 (39)	-2.52 (17)	1.08 (45)	NA	0.42 (38)	NA
***t*, p**	0.74	**-2.70***	1.68	NA	0.52	NA
Hum/Sit x̄ (df)	0.34 (39)	-1.93 (17)	0.27 (45)	NA	0.30 (38)	NA
***t*, p**	0.63	-1.85	0.58	NA	0.55	NA
Rad/Sit x̄ (df)	0.13 (38)	-1.54 (16)	0.37 (45)	NA	-0.02 (38)	NA
***t*, p**	0.32	-1.99	0.89	NA	-0.04	NA

(* $p \leq 0.05$; ** $p \leq 0.01$ # significant difference in age between groups.)

Table 6.12: *Student's t*-test on anthropometric variables of tribes measured in 1930s and 1950s: head and face measurements.

Tribe (group)	Mean Difference B5 - T11 Nyanganytatjara (G36)		Mean Difference B6 - T9 Mandjindja (G34)		Mean Difference B7 - T13 Ngatatjara (G38)	
	M #	F	M	F	M	F
Head L $\bar{x}$ (df)	-1.28 (39)	-0.48 (17)	-3.53 (45)	NA	-1.76 (39)	NA
t, p	-0.78	-0.17	-1.71	NA	-0.97	NA
Head B $\bar{x}$ (df)	-1.08 (39)	0.16 (17)	-1.78 (45)	NA	-0.98 (39)	NA
t, p	-0.80	0.11	-1.26	NA	-0.74	NA
Head H $\bar{x}$ (df)	-3.58 (39)	3.12 (17)	-0.20 (45)	NA	-2.65 (39)	NA
t, p	-1.60	1.41	-0.13	NA	-1.36	NA
Min Fron D $\bar{x}$ (df)	-4.33 (39)	-2.13 (17)	-3.13 (45)	NA	-3.69 (39)	NA
t, p	**-3.33****	-1.09	**-2.25***	NA	**-2.61***	NA
Bizyg $\bar{x}$ (df)	3.71 (39)	-1.49 (17)	-1.93 (45)	NA	-3.07 (39)	NA
t, p	**-2.75****	-0.69	-1.53	NA	-1.58	NA
Bigonial $\bar{x}$ (df)	-4.33 (39)	-5.97 (17)	-2.27 (45)	NA	-3.98 (39)	NA
t, p	**-2.82****	**-3.22****	-1.36	NA	**-2.06***	NA
Tot Fac H $\bar{x}$ (df)	-2.36 (38)	-0.38 (16)	-2.97 (45)	NA	-2.65 (39)	NA
t, p	-1.16	-0.14	-1.70	NA	-1.77	NA
Up Fac H $\bar{x}$ (df)	-1.31 (38)	0.53 (16)	-3.93 (45)	NA	-3.11 (39)	NA
t, p	-0.80	0.22	**-2.93****	NA	**-2.98****	NA
Nose H $\bar{x}$ (df)	0.49 (39)	1.26 (17)	-1.88 (45)	NA	-2.41 (39)	NA
t, p	0.39	0.89	-1.54	NA	**-2.29***	NA
Nose B $\bar{x}$ (df)	-0.50 (39)	-0.90 (17)	-0.38 (45)	NA	1.33 (39)	NA
t, p	-0.55	-0.83	-0.39	NA	1.45	NA
Nose D $\bar{x}$ (df)	2.12 (39)	1.07 (17)	0.03 (45)	NA	1.28 (39)	NA
T, p	**2.91****	1.21	0.05	NA	1.68	NA
Mand D $\bar{x}$ (df)	-1.79 (38)	-0.23 (17)	1.98 (45)	NA	-2.04 (39)	NA
t, p	-1.74	-0.14	**-2.19***	NA	**-2.24***	NA

(* $p \leq 0.05$; ** $p \leq 0.01$ # significant difference in age between groups.)

Table 6.13: *Student's t*-test on anthropometric variables of tribes measured in 1930s and 1950s: head and face indices.

Tribe (group)	Mean Difference B5 - T11 Nyanganytatjara (G36)		Mean Difference B6 - T9 Mandjindja (G34)		Mean Difference B7 - T13 Ngatatjara (G38)	
	M #	F	M	F	M	F
N I (H/B) $\bar{x}$ (df)	-2.11 (39)	-4.31 (17)	2.53 (45)	NA	8.29 (39)	NA
t, p	-0.66	-1.41	0.74	NA	**2.97****	NA
N I (B/D) $\bar{x}$(df)	5.15 (39)	4.05 (17)	0.87 (44)	NA	0.79 (39)	NA
t, p	**2.69***	1.66	0.55	NA	0.42	NA
C I $\bar{x}$ (df)	-0.10 (39)	0.17 (17)	0.35 (45)	NA	0.12 (39)	NA
t, p	-0.12	0.16	0.50	NA	0.15	NA
C M $\bar{x}$ (df)	-1.99 (39)	0.94 (17)	-1.83 (45)	NA	-1.79 (39)	NA
t, p	-1.48	0.65	-1.37	NA	-1.45	NA
CF I $\bar{x}$ (df)	-1.89 (39)	-1.21 (17)	-0.09 (45)	NA	-1.44 (39)	NA
t, p	-1.58	-0.83	-0.11	NA	-1.23	NA
TF I $\bar{x}$ (df)	0.47 (38)	0.59 (16)	-1.03 (45)	NA	-0.20 (39)	NA
t, p	0.33	0.25	-0.80	NA	-0.18	NA

(* $p \leq 0.05$; ** $p \leq 0.01$ # significant difference in age between groups.)

Birdsell argued that this real increase in weight (fatness) was due to differences in diet, resulting from the adoption of introduced foodstuffs (Birdsell 1993: 304-308). After European colonisation and the dislocation of Aboriginal people from their traditional fisher-hunter-gatherer economies, they became increasingly dependant on the foods supplied at government settlements, Christian missions and stations (ranches). The typical station ration, for instance, consisted of flour, sugar, jam and meat, although this could be supplemented by continued hunting and gathering (Peterson 1978: 30; Hetzel

1978: 41). The switch from a diet of often minimally processed plants (fruits, seeds, tubers, grains) and meats, to one primarily based on highly refined flour and sugary foods, combined with a more sedentary lifestyle, led to an increase in body weight and its associated health problems (Hetzel 1978). Birdsell estimated that the change from "wild" to station rations led to a gain of up to 20 pounds (~9kg) in weight (Birdsell, 1993: 304). However, a comparison of the weights of "bush-born" and "station-born" cohorts from other tribes produced conflicting results (Birdsell 1993: 304).

Whilst the increase in weight in these Western Desert tribes is attributed by Birdsell to dietary changes, the increase in stature is not. Birdsell argued that the differences in stature were essentially sampling artefacts and he noted that different "hordes" from each tribe were measured during the later expeditions (Birdsell 1993: 305; 338). He was to use similar reasoning to refute claims by Barrett and Brown (1977) for a secular increase in stature in the Aboriginal people studied at Yuendumu in Central Australia (primarily Warlpiri, mixed with Ngalia and Pintubi) (Birdsell 1993: 430). In his 1993 monograph, Birdsell also compared the stature of the "bush-born" and "station-born" cohorts from some of the western tribes, as well as parent-child dyads from the Cairns rainforest region, and found no evidence of stature increase over time (Birdsell 1993: 308; 430).

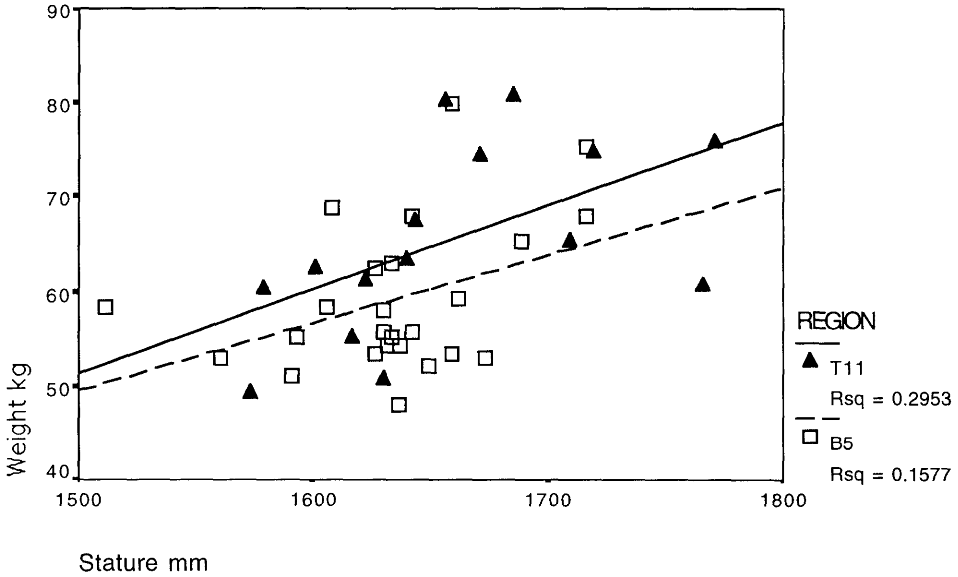


Figure 6.3: Scatterplot of stature vs weight for group 36, Nyanganytatjara. (Comprises of the B5 group measured in the 1938-39 expedition and T11 group measured during the 1952-54 expedition.)

As can be seen in Tables 6.10 - 6.13, a range of body and cranio-facial measurements show varying degrees of difference over time. Most differences are positive in value the exception being in some nasal measurements, however the only variable apart from weight to show a consistent significant increase in all three male groups, is minimum frontal diameter. The increase in this measurement in the female group is not significant.

As for other measurements, in the Nyanganytatjara radius length, femur length, biacromial diameter, sitting height, bizygomatic diameter and bigonial diameter are significantly larger, and nose depth is significantly smaller, in the later male group and only bigonial breadth and tibia/sitting height ratio are significant larger in the later female group. In the Mandjindja sitting height, upper facial height and mandibular depth are significantly larger in the later group. In the Ngatatjara, calf circumference, upper facial height, bigonial diameter, nose height and mandibular depth are all significantly larger in the later group. The increases in many cranio-facial measurements are probably related to the increases in overall body size and may also be related to increases in tissue thickness (eg. in the facial diameters).

Supporting the possibility of a secular trend effect in facial dimensions, Brown (1976) reported changes over a 30-year time-span in head and face measurements in young Aboriginal men and women at Yuendumu. These changes included increases in head length, head breadth, bizygomatic diameter, bigonial diameter and morphological facial height. His study revealed that whilst changes occurred in his younger sample group (average age 19, but ranging from below 15 to 35), the same could not be said for an older group (aged 23-65) (Brown 1976: 199-200). These "older" adults, however, were measured by other researchers, adding the possibility of interobserver error. Well aware of this problem, Brown was cautious about the causes and significance of the observed changes, but noted that studies of other population groups undergoing similar changes to lifestyle (Apache and Skolt-Lapps) had also shown secular changes in cranio-facial size and shape (Brown 1976: 202-204).

It is difficult to compare Brown's study with the present one, mainly as the age range of Birdsell's sample is more akin to the "older" of Brown's groups, which not only combine the measurements of more than one observer, but were collected over a longer time period than were Birdsell's samples. Yet, as can be seen in the tables above there are increases observed in the comparable variables in all groups, but only in the bizygomatic and bigonial diameters are significant differences observed and, then, not in all groups.

Where differences in body shape (as measured by indices) occur, they appear to be primarily associated with the changes to body weight. The exceptions to this are the significant changes to relative sitting height in the Nyanganytatjara and Mandjindja males and the increase in tibia length/sitting height in the female group. In fact it appears that whilst the males of the Nyanganytatjara became stockier, the females became more linear. Although the sample sizes of the comparative groups are small, this result may point to differential access to the introduced foodstuffs between the sexes.

From the above results it appears likely that tribes who had been in contact with a European-style diet for a longer period of time would be fatter, perhaps somewhat taller, and also possibly have differences in facial size associated with the increase in overall body size and/or increases in soft-tissue thickness. This would apply especially to those tribes in areas of early occupation (the coastal areas of the east and southwest) that were measured during Birdsell's first expedition. It is hard to gauge the differences this may make to the analysis - certainly any conclusions reached regarding body size and shape differences between populations should take into account how long the population had been exposed to a new diet and lifestyle.

Overall however, it was concluded from the above results that the twice-measured groups were alike enough in most measurements of size and shape to be pooled together for further analyses.

6.5 ANALYSIS OF VARIANCE

An Analysis of Variance (ANOVA) on all absolute and ratio variables found highly significant differences between the 57 male and 45 female sample groups. Such a result is predictable given the large geographic span over which these samples were taken. Values for *F* and degrees of freedom are presented in Tables 6.14 - 6.17, below. Such a result stands in contrast to Abbie's conclusion that the indigenous people of Australia were morphologically homogeneous (Abbie 1968, 1975).

Table 6.14: One Way ANOVA between sample groups for body measurement (and including age) of male and female data sets.

Variable	**DF (Model, Error, Total)**	***F* Male**	**DF (Model, Error, Total)**	***F* Female**
Age	56, 1356 1422	5.87***	44, 834, 878	2.85***
Weight	56, 1358, 1414	6.06***	44, 812, 856	5.16***
Stature	56, 1362, 1418	12.40***	44, 832, 876	9.75***
Hum L	56, 1361, 1417	9.14***	44, 833, 877	9.78***
Rad L	56, 1360, 1416	8.07***	44, 827, 871	5.82***
Fem L	56, 1357, 1413	9.73***	44, 812, 856	9.71***
Tib L	56, 1358, 1414	11.59***	44, 832, 876	10.13***
Biacromial	56, 1362, 1418	4.69***	44, 833, 877	5.34***
Bi-iliac	28, 535, 563	5.94***	16, 144, 160	5.60***
Sitting Hght	56, 1360, 1416	9.97***	44, 826, 870	7.99***
Calf Circ	56, 1347, 1403	5.48***	44, 829, 873	6.34***

(*** $p < 0.001$)

Table 6.15: One Way ANOVA between sample groups for body indices of male and female data sets.

Variable	DF (Model, Error, Total)	*F* Male	DF (Model, Error, Total)	*F* Female
SA	56, 1356, 1412	8.11***	44, 809, 853	5.70***
SA /M	56, 1356, 1412	5.22***	44, 809, 853	5.28***
RPB	28, 534, 562	4.55***	16, 143, 159	3.48***
RSB	56, 1359, 1415	6.22***	44, 830, 874	6.36***
R Sit H	56, 1357, 1413	4.03***	44, 826, 870	3.64***
PI	56, 1356, 1412	5.50***	44, 809, 853	5.92***
Calf/Tib	56, 1343, 1399	5.56***	44, 828, 872	6.53***
Rad/Hum	56, 1358, 1415	2.50***	44, 827, 871	3.48***
Tib/Fem	56, 1354, 1410	3.81***	44, 812, 856	2.74***
Interm	56, 1347, 1403	3.54***	44, 805, 849	2.89***
Fem/Sit	56, 1351, 1407	3.42***	44, 803, 847	4.76***
Tib/Sit	56, 1352, 1408	4.71***	44, 823, 867	4.47***
Hum/Sit	56, 1355, 1411	3.00***	44, 824, 868	4.45***
Rad/Sit	56, 1354, 1410	2.64***	44, 818, 862	2.61***

(*** $p < 0.001$)

Table 6.16: One Way ANOVA between sample groups for head and face measurements of male and female data sets.

Variable	DF (Model, Error, Total)	*F* Male	DF (Model, Error, Total)	*F* Female
Head L	56, 1366, 1422	4.04***	44, 834, 878	2.76***
Head B	56, 1366, 1422	7.03***	44, 835, 879	5.88***
Head H	56, 1365, 1421	2.12***	44, 835, 879	3.65***
Min Front D	56, 1366, 1422	3.86***	44, 833, 877	4.08***
Bizygomatic	56, 1367, 1423	6.09***	44, 834, 878	3.99***
Bigonial	56, 1364, 1420	6.08***	44, 835, 879	6.10***
Tot Facial H	56, 1240, 1296	5.34***	44, 781, 825	4.84***
Upp Facial H	56, 1194, 1250	6.00***	44, 765, 809	3.66***
Nose H	56, 1363, 1419	5.32***	44, 834, 878	4.72***
Nose B	56, 1366, 1422	5.72***	44, 833, 877	4.76***
Nose D	56, 1365, 1421	4.73***	44, 834, 878	3.81***
Mandibular D	56, 1210, 1266	3.29***	44, 777, 821	3.81***

(*** $p < 0.001$)

Table 6.17: One Way ANOVA between sample groups for head and face indices of male and female data sets.

Variable	DF (Model, Error, Total)	*F* Male	DF (Model, Error, Total)	*F* Female
NIB	56, 1363, 1419	3.46***	44, 832, 876	2.11***
NID	56, 1365, 1421	5.19***	44, 833, 877	3.69***
CI	56, 1366, 1422	5.84***	44, 834, 878	4.60***
CM	56, 1365, 1421	4.25***	44, 834, 878	3.67***
CFI	56, 1366, 1422	6.80***	44, 834, 878	3.30***
TFI	56, 1230, 1286	5.22***	44, 781, 825	2.93***

(*** $p < 0.001$)