Journal of Human Evolution xxx (2010) 1–20

Contents lists available at ScienceDirect

Journal of Human Evolution

journal homepage: www.elsevier.com/locate/jhevol

Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?

Peter Brown

Palaeoanthropology, Faculty of Arts and Sciences, University of New England, Armidale, NSW 2351, Australia

ARTICLE INFO

Article history:
Received 17 June 2009
Accepted 26 May 2010

Keywords:
Australia
Java
Pleistocene
Homo sapiens
Homo erectus
Intentional cranial modification
Size adjustment
Nacurrie
Coobool Creek
Kow Swamp

ABSTRACT

There has been a protracted debate over the evidence for intentional cranial modification in the terminal Pleistocene Australian crania from Kow Swamp and Coobool Creek. Resolution of this debate is crucial to interpretations of the significance of morphological variation within terminal Pleistocene–early Holocene Australian skeletal materials and claims of a regional evolutionary sequence linking Javan *Homo erectus* and Australian *Homo sapiens*. However, morphological comparisons of terminal Pleistocene and recent Australian crania are complicated by the significantly greater average body mass in the former. Raw and size-adjusted metric comparisons of the terminal Pleistocene skeleton from Nacurrie, south-eastern Australia, with modified and unmodified *H. sapiens* and *H. erectus*, identified a suite of traits in the frontal, parietal, and occipital bones associated with intentional modification of a neonate's skull. These traits are also present in some of the crania from Kow Swamp and Coobool Creek, which are in close geographic proximity to Nacurrie, but not in unmodified *H. sapiens* or Javan *H. erectus*. Frontal bone morphology in *H. erectus* was distinct from all of the Australian *H. sapiens* samples. During the first six months of life, Nacurrie's vault may have been shaped by his mother's hands, rather than though the application of fixed bandages. Whether this behaviour persisted only for several generations, or hundreds of years, remains unknown. The reasons behind the shaping of Nacurrie's head, aesthetics or otherwise, and why this cultural practice was adopted and subsequently discontinued, will always remain a matter of speculation.

Introduction

Perhaps one of the earliest and certainly most persistent debates involving Australia concerns the origins of the country's indigenous human inhabitants. From first contact, European explorers assumed that the Australian Aborigines had come to Australia from somewhere else (Brown, 1997a,b). Initially, external appearance suggested an African origin (Dampier, 1697). James Cook later dismissed this on cultural and physical grounds (Wharton, 1893), distinguishing indigenous Australians from their contemporaries in Asia and the Pacific. Huxley (1870: 405) commented on the remarkable circumstance, in that "no trace of the Australoid type has been found in any of the islands of the Malay archipelago". More than a century later this "remarkable circumstance" remains an area of conflict and confusion for anthropologists concerned with the origins and dispersions of *H. sapiens* in the region (Dubois, 1922; Birdsell, 1967, 1993; Bowler et al., 1972; Thorne and Macumber, 1972; Howells, 1976; Macintosh and Larnach, 1976; Thorne and Wolpoff, 1981; Brown, 1987b, 2000; Habgood, 1989; Hanhirara, 1992; Stringer, 1998; Antón and Weinstein, 1999; Bowler and Magee, 2000; Adcock et al., 2001; Cooper et al., 2001; Wolpoff et al., 2001; O'Connell and Allen, 2004; Curnoe and Thorne, 2006). Anatomically modern *H. sapiens* could have arrived in Australia as early as 40–45 ka (O'Connell and Allen, 2004); however, the earliest reliably dated human skeletal evidence may only date to 26 ka (Bowler et al., 1970, 1972; Bowler and Magee, 2000), and with the possible exception of Niah Cave (Brothwell, 1960; Kennedy, 1977; Barker et al., 2007), their late Pleistocene south-east Asian antecedents remain unknown.

While there is currently no evidence of *H. sapiens* in south-east Asia predating their arrival in Australia (David et al., 1997; Fifield et al., 2001; O'Connell and Allen, 2004), it is generally argued that humans must have moved through the Indonesian archipelago to reach the Sahul Shelf (Birdsell, 1977). Claims of an earlier evolutionary sequence linking Indonesian *Homo erectus* with later Australians have a long history (Klaatsch, 1908; Weidenreich, 1945; Thorne and Macumber, 1972; Larnach and Macintosh, 1974; Thorne and Wolpoff, 1981; Wolpoff et al., 2001). In particular, after the discovery and excavation of the terminal Pleistocene human skeletons from Kow Swamp, south-eastern Australia, Thorne and

---

E-mail address: pbrown3@une.edu.au.

0047-2484/$ – see front matter Crown Copyright © 2010 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.jhevol.2010.05.007

Macumber (1972: 319) described their frontal bones as preserving "an almost unmodified eastern *erectus* form, specifically that of Javan Pithecanthropines." This regional evolutionary sequence was further developed by Thorne and Wolpoff (1981), who, while stressing the difference in grade, identified a number of morphological clade features, which they argued were shared by Javan *H. erectus* (Sangiran 17) and Kow Swamp *Homo sapiens* (KS1, KS5 and Cohuna). Features suggestive of this relationship included the flatness of the frontal in the sagittal plane, posterior position of minimum frontal breadth, distinct pre-bregmatic eminence, and low position of maximum cranial breadth.

Critiques of Thorne and Wolpoff's original regional continuity model pointed out that many of their traits were inappropriate. Specifically, critics argued that the traits were either absent in the majority of terminal Pleistocene Australians or were primitive retentions expressed only in male crania, found at similar frequencies in other geographic regions, and linked to body mass (Bräuer, 1989; Groves, 1989; Brown, 1992b; Lahr, 1994; Lahr and Wright, 1996). Importantly, the skeletons that provide the earliest evidence of *H. sapiens* in Australia (Lake Mungo 1 and 3) do not have the frontal and facial features that have been claimed to demonstrate evolutionary continuity between Javan *H. erectus* and later Australians *H. sapiens* (Bowler et al., 1970, 1972; Bowler and Thorne, 1976; Brown, 1987b, 2000; Thorne et al., 1999; Bowler and Magee, 2000; Gillespie and Roberts, 2000). More recently, analysis of mtDNA and Y chromosome variation in Aboriginal Australians and Melanesians confirmed that all Australian lineages fall within the mitochondrial branches M and N, and the Y chromosomal founders C and F, which are associated with the exodus of modern humans from Africa ~50–70 ka (Hudjashov et al., 2007). There was no evidence of archaic maternal or paternal lineages in Australia, further weakening arguments for regional continuity with *H. erectus*.

The morphology of the frontal bone and perceptions about cranial size and robusticity in the late Pleistocene–early Holocene have also contributed to a debate over the significance of variation in fossil and recent Australians (Birdsell, 1967, 1993; Thorne, 1976, 1977, 1984; Brown, 1987a, 1992b, 2000; Antón and Weinstein, 1999; Curnoe and Thorne, 2006; Pardoe, 2006; Durband, 2008b). Variation is either interpreted as being beyond what would be expected from the migration of a single, biologically and culturally homogenous founder population (Thorne, 1977; Curnoe and Thorne, 2006), or what could be predicted from evolutionary processes of gene flow, selection, and drift in a continent as environmentally diverse as Australia (Lindsell, 2001; Pardoe, 2006; Gilligan and Bullbeck, 2007). While there is some regional variation in Pleistocene archaeological assemblages, there is no material culture evidence consistent with the presence of two, or more, culturally and biologically distinct late Pleistocene populations (Mulvaney and Kamminga, 1999; Hiscock, 2008). Consistent with the archaeological evidence, a recent analysis of mtDNA and Y chromosome data suggests that Australia and New Guinea were colonized by the same migratory wave ~50 ka, with considerable isolation after initial arrival (Hudjashov et al., 2007).

Additional complications include the evidence for significantly greater average body size in terminal Pleistocene Australians (Brown, 1987a, 1992a,b), poor preservation and insecure dating of Australian human skeletal collections (Bowler et al., 1970; Thorne, 1975; Brown, 1989, 2000; Thorne et al., 1999; Bowler and Magee, 2000; Gillespie and Roberts, 2000), and analytical difficulties stemming from repatriation of skeletal remains for reburial in the 1980s (Mulvaney, 1991). Contemporary researchers no longer have access either to original fossils or large comparative recent Aboriginal skeletal samples, and are thus required to use published data. Alternatively, researchers may generate new data from replicas of undemonstrated accuracy (e.g., Antón and Weinstein, 1999; Curnoe, 2007, 2009; Durband, 2008a,b).

A parallel and important debate concerns the possible influence of intentional modification of infant crania on adult morphology at the terminal Pleistocene–early Holocene sites of Kow Swamp (Brothwell, 1975; Brown, 1981b; Antón and Weinstein, 1999; Curnoe and Thorne, 2006; Clark et al., 2007; Curnoe, 2007, 2009; Durband, 2008a) and Coobool Creek (Brown, 1981b, 1989; Antón and Weinstein, 1999; Durband, 2008a,b). This is crucial to an understanding of the biological basis of skeletal variation in terminal Pleistocene Australia, particularly in relation to the morphology of the fronto-facial region and cranial dimensions more broadly, and claims of evolutionary continuity with Javan *H. erectus*.

The aim of this research is to examine the evidence for intentional cranial modification and morphological continuity with Indonesian *H. erectus*, in one of the few directly dated terminal Pleistocene skeletons from south-eastern Australia, Nacurrie 1, using both unadjusted and size-adjusted data. Previous analyses of variation between terminal Pleistocene (TP) and near contemporary Australian crania, and TP Australians and Javan *H. erectus*, have focused on morphological and metric differences unadjusted for size (Thorne and Macumber, 1972; Thorne and Wilson, 1977; Thorne and Wolpoff, 1981; Brown, 1987a, 1989, 1992b). As the primary objective of this analysis was to identify individuals of similar shape regardless of size, data were size-adjusted to highlight allometric shape differences between individual specimens that may otherwise have been subverted by differences in body size (Mosimann and James, 1979; Darroch and Mosimann, 1985; Jungers et al., 1995). Size adjustment was performed using the shape ratios developed by Mosimann (Mosimann, 1975; Mosimann and James, 1979) that retain size-related (allometric) shape (von Cramon-Taubadel et al., 2005; Ackermann, 2005).

Morphological and statistical comparisons are made between Nacurrie 1 and artificially modified crania from New Britain, the Arawe (Blackwood and Danby, 1955), unmodified crania from New Britain and Australia, and Indonesian *H. erectus*. Emphasis is placed on the parts of the neurocranium that are modified by intentional modification of a neonate's skull and are preserved in Nacurrie 1, and a large proportion of the terminal Pleistocene–early Holocene crania from Australia (Brown, 1987a, 1989). As the majority of the Australian samples, including Nacurrie 1, were repatriated to Aboriginal communities for reburial two decades ago, this study was constrained by available data. This precluded the application of more recently developed analytic procedures, such as three-dimensional geometric morphometrics (Slice, 2007) or high-resolution computed tomography. The latter would have been particularly useful in examining the ontogenetic changes in cranial vault bone thickness (Skrzat et al., 2002) and endocranial surface contours and volumes associated with cranial modification (Baba et al., 2003).

Background: the Nacurrie site

Between 1948 and 1950, George Murray Black collected skeletons from Aboriginal cemeteries in the central Murray River region of south-eastern Australia for the former Australian Institute of Anatomy, Canberra, and the Department of Anatomy, Melbourne University (Ray, 1959; Sunderland and Ray, 1959; Brown, 1981b, 1989; Robertson, 2007). In August of 1949, Black excavated a number of highly mineralized and carbonate encrusted skeletons from a sand ridge near Merran Creek, not far from Nacurrie railway siding and north of Swan Hill (letters from G.M. Black to L.J. Ray, 1949–1950) (Fig. 1). The burials were initially exposed when the sand ridges were being ripped to remove rabbit burrows, which resulted in parts of the skeletons being dragged to the surface. After

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

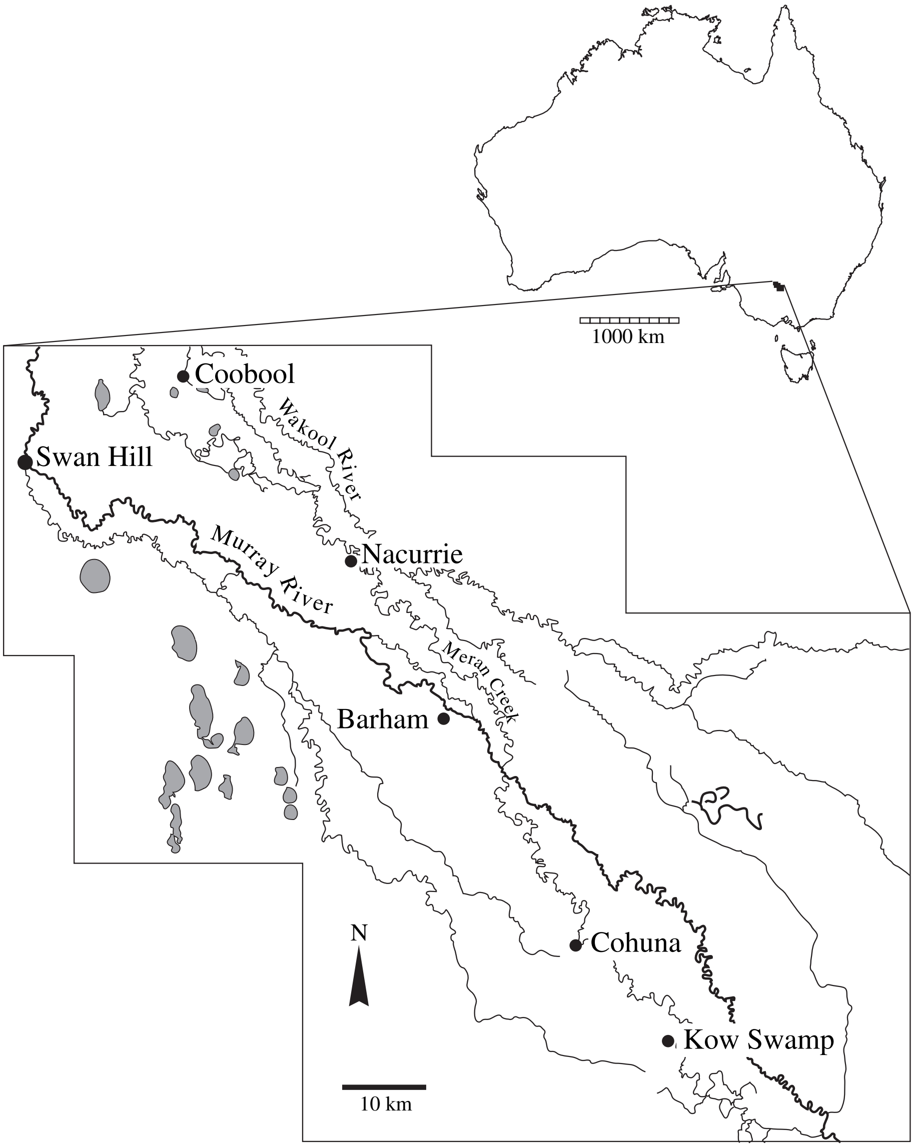

Figure 1. Location of Nacurrie, Coobool Creek, and Kow Swamp in the central Murray River region of south-eastern Australia.

further excavation, the better-preserved skeletons were taken to Melbourne and stored with the remainder of the Murray Black Collection in the Department of Anatomy. In February 1971, Professor Les Ray, former Head of the Department of Anatomy, sent parts of the most complete skeleton from this site to Professor N.W. G. Macintosh, former Head of Department of Anatomy at Sydney University, for cleaning, reconstruction, and analysis (correspondence supplied by Mrs. A. Macintosh). Macintosh and Larnach (1976: 117) briefly refer to this individual as the "Murrabit skull" and remark that it "is almost an identical twin to Cohuna (Macintosh, 1952a,b; Macumber and Thorne, 1975; Brown, 1989). Its frontal curvature index is very nearly identical. It has a massive mandible." After Macintosh's death in 1977, the Nacurrie skeleton was returned to Melbourne.

In 1980, Professor Ray and I discussed the Nacurrie material with the aim of jointly bringing Macintosh's work to fruition. This project, in turn, was not completed due to Professor Ray's unexpected illness and death in 1981. In 1983, reconstruction of the skeleton resumed at the University of New England, and parts of the facial skeleton, cranial base, and postcrania, which had not been available to Macintosh, were integrated with the rest of the skeleton. Just as the entire skeleton had been cleaned and reconstructed in 1984, a change in the Victorian State Relics Legislation resulted in all of the G.M. Black collection, including Nacurrie, being impounded and eventually repatriated to Aboriginal communities for reburial (Mulvaney, 1991).

Macintosh, through the New Zealand Institute of Nuclear Sciences, first attempted radiocarbon dating of the Nacurrie skeleton in 1971. Dating of secondary carbonates removed from the external surface of the cranial vault suggested to Macintosh that Nacurrie was somewhat younger than Keilor, which was dated to approximately 12 ka (Brown, 1989). In 1976, a cast was made of one femur so that the original could be used to obtain a radiocarbon date from the bone collagen fraction. This project was not completed due to Macintosh's death. Finally, an AMS collagen date of 11440 ± 160 ka (NZA 1069) was obtained from postcranial bone fragments, confirming Macintosh, Ray, and Larnach's belief in the antiquity of Nacurrie (Brown, 1994a).

The Nacurrie skeleton was reasonably complete, apart from the thoracic cavity and hands, with postdepositional damage restricted to the right side of the vault, basicranium, mid-facial skeleton, and articular surfaces of some limb bones. Most of this postmortem

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

damage, with clean-fractured surfaces, occurred when the heavily encrusted and articulated skeleton was accidentally dragged to the surface by tractor tines. There was no evidence of postmortem distortion in any of the skeletal elements, and the external and internal surfaces were free of expansion and compression cracks (Fig. 2). Excellent bone preservation had resulted from a combination of alkaline sand ridge soils, the deposition of secondary carbonates around external bone surfaces, and bone mineralization. A brief description of the skeleton, made for a general audience, was published in 1994 (Brown, 1994a).

The Nacurrie skeleton was from a relatively tall, broad shouldered, and robustly built adult male, who seems to have had an active, combative, and at times painful life (Table 1). Cranial and postcranial dimensions in Nacurrie are consistent with the greater skeletal size and robusticity described for terminal Pleistocene Australians, relative to their mid-Holocene and recent counterparts from the same geographical region (Brown, 1987b, 1992a,b). Over the first 5 k.yr. of the Holocene there was a reduction in stature, skeletal robusticity, brain size, and tooth size in south-eastern Australia. The mechanisms behind this reduction in body mass remain unclear, but it was not associated with dramatic changes in food preparation technology, increasing population densities, or a shift to more sedentary lifestyles (Brown, 1992b; Mulvaney and Kamminga, 1999; Brown and Maeda, 2004), as may have happened in East Asia (Brace et al., 1984; Pechenkina et al., 2002; Brown and Maeda, 2004) and other parts of the Old World (Le Blanc and Black, 1974; Calcagno, 1986).

Figure 2. Left lateral (above) and facial views of Nacurrie 1 prior to its repatriation in 1984. The facial skeleton was digitally reconstructed by replacing damaged sections of the Nacurrie maxillae with the corresponding facial parts from the metrically similar Coobool Creek 65 (Brown, 1989).

Table 1
Descriptive statistics for postcranial dimensions, humeral and femoral robusticity, postcranial indices, and estimated body mass and stature in male and female late Holocene Aborigines from south-eastern Australia and Nacurrie 1, along with stature and body mass for Aborigines living in the same geographic region during 1938–1939.

	Sex	*N*	$\bar{X}$	SD	*P*	Nacurrie
R. femur max length	M	29	455.5	27.70		497.0
	F	41	426.4	19.42	*	
R. femur midshaft a-p d.	M	29	29.2	1.99		30.0
	F	42	23.6	2.18	*	
R. femur midshaft trans d.	M	29	25.3	1.36		28.0
	F	42	23.2	1.56	*	
R. femoral head d.	M	29	44.3	3.38		54.0
	F	41	38.9	2.64	*	
Femoral shaft robust. index**	M	29	12.0	0.75		11.7
	F	40	11.0	0.52	*	
R. humerus max length	M	35	330.6	18.52		366.0
	F	44	307.0	18.01	*	
R. humeral vertical head d.	M	40	43.6	2.13		49.0
	F	50	37.8	2.04	*	
R. humerus midshaft major d.	M	36	22.3	1.17		25.0
	F	46	18.4	1.59	*	
R. humerus midshaft minor d.	M	36	16.9	1.39		20.0
	F	46	13.5	1.32	*	
Humeral shaft robust. index	M	35	11.9	1.01		12.3
	F	44	10.2	0.79	*	
R. clavicle max length	M	88	139.6	8.84		162.0
	F	92	125.3	7.98	*	
R. acetabulum vertical d.	M	49	51.5	2.86		60.0
	F	49	46.0	1.91	*	
Humerofemoral index	M	23	72.5	1.71		73.6
	F	33	72.6	1.45	NS	
Clavicofemoral index	M	26	31.3	1.53		32.6
	F	35	29.4	2.43	*	
Clavicohumeral index	M	35	42.8	2.38		44.2
	F	44	40.7	2.96	*	
Body mass estimate (kg)***	M	33	59.2	9.44		83.8
	F	44	53.2	6.67	*	
Body mass Birdsell 18–34 yrs	M	8	60.2	9.57		
	F	2	53.5		_	
Body mass Birdsell >34 yrs	M	42	64.2	8.76		
	F	12	70.4	8.46	NS	
Stature estimate****	M	35	166.8	5.69		175.2
	F	44	156.6	5.11	*	
Stature Birdsell 18–34 yrs	M	8	160.3	5.60		
	F	2	153.1		_	
Stature Birdsell >34 yrs	M	42	164.6	6.08		
	F	12	152.7	3.51	*	

t-test of differences between male and female means: *, $p < 0.01$; NS, not significant. ** calculated using maximum femur length, not oblique length, *** estimated from femoral head diameter using regression equations in Ruff et al. (1997), adjusted downwards by 10%, as recommended by the authors. Male equation used for males including Nacurrie 1, female equation for females. ****calculated using male and female African-American equations for maximum femur length in Trotter and Gleser (1952). Body mass and stature data for living "full-blooded" Aborigines from the Murray and Darling drainage region collected by Joseph Birdsell in 1938–1939 (Birdsell, 1993), raw data archived at the South Australian Museum. Birdsell's sample has been subdivided on the basis of age due to the influence of diet and diabetes on body mass, particularly in women older than 34 yrs (O'Dea et al., 1993).

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

Nacurrie had poorly healed bilateral fractures of both forearms, a healed, depressed fracture on the right parietal, and a healed fracture of the right distal fibula that is ankylosed to the tibia. Similar fractures of the forearm and cranial vault are often present in prehistoric male and female Aboriginal skeletal material as a result of traditional methods of dispute settlement (Brown, 1994b, 1989; Knuckey, 1992). A description and photographs of Nacurrie's fractured forearms can be found in Webb (1995: 70–73), who unfortunately neglects earlier work with the skeleton. The external auditory meati had well-developed auditory exotoses, which were fairly common in populations living along the Murray River who obtained food resources from seasonally cold, fresh water (Roche, 1964; Kroon et al., 2002). There is also flattening and extensive arthritic remodeling of the remaining temporal eminence, which, while associated with tooth wear and age (Richards and Brown, 1981), was not present in the older adults from Kow Swamp (KS5) or Coobool Creek (Brown, 1989). Nacurrie's mandibular and maxillary teeth were extremely worn, with an edge-to-edge anterior bite, compensatory mesial migration and eruption, and pulp canal exposure due to extreme tooth wear in five of the remaining teeth (Fig. 2). This degree of tooth wear was common amongst traditional Aboriginal communities. A combination of minimal premasticatory preparation of tough, abrasive foods, using teeth as tools and bruxism, usually resulted in extensive crown reduction and pulp canal exposure by early middle age (Campbell, 1925, 1939; Barrett, 1977; Brown, 1989, 1992a).

Materials and methods

Background to sample selection and methodology

Numerous authors have documented size and shape differences that characterize the cranial vaults of modern *H. sapiens* and *H. erectus* (Weidenreich, 1943, 1951; Howells, 1973; Santa Luca, 1980; Rightmire, 1990; Baba et al., 2003; Rightmire et al., 2006), and it would be difficult for an experienced observer to confuse these taxa. Similarly, morphological distinctions between intentionally modified and unmodified human crania are usually not subtle, with obvious differentiation in the curvature of the major vault bones (Goldstein, 1940; Brown, 1981a; Cybulski, 1989; Antón and Weinstein, 1999; Friess and Baylac, 2003; O'Brien and Sensor, 2004; Tubbs et al., 2006; Perez, 2007). However, depending upon the method used to alter the shape of the infant's vault, the diligence and expertise of the child's mother, and social pressures to produce a uniform head shape, there may be considerable morphological variation both within communities and between siblings (Dingwall, 1931; Blackwood and Danby, 1955). Some forms of modification, e.g., cradle boards (Cybulski, 1989; Manriquez et al., 2006; Rhode and Arriaza, 2006; Lekovic et al., 2007), were also responsible for more extreme alterations in shape than head binding, caps, or repetitive manual pressure (Miklouho-Maclay, 1882; Dingwall, 1931; Blackwood and Danby, 1955; Kiszelly, 1989; Benus et al., 1999), but importantly, all methods alter the normal size and shape relationships found in the human cranial vault.

A survey of the literature indicated that the antero-posterior curvature of the frontal, parietal, and occipital bones, the breadth and height of the cranial vault, the morphology of the frontal bone, the thickness of the cranial vault bones, and size relationships could be used to distinguish between modified and unmodified *H. sapiens*, as well as differentiating *H. sapiens* from *H. erectus*. The impact of intentional modification on cranial morphology and size were first examined through comparison of crania from two different communities on New Britain, the Arawe and Tolai. Historically, the Arawe intentionally altered the shape of their infant's heads through a series of tight bandages applied shortly after birth, and kept in place for the first four to six months of life (Blackwood and Danby, 1955) (Fig. 3). The Tolai, who are linguistically and culturally distinct from the Arawe, did not modify the shape of their children's heads (Bonin, 1936; Howells, 1989). The Arawe ($n = 55$) and Tolai ($n = 67$) data were obtained from collections in the Natural History Museum London, the former Institute of Anatomy, Canberra, the Australian Museum, Sydney, the South Australian Museum, Adelaide, and the Departments of Anatomy at Melbourne and Sydney Universities. As the pelvic morphology and relatively large skeletal dimensions of Nacurrie 1 indicated that the skeleton was from a male (Brown, 1994a) (Table 1), and as I wished to minimise the potentially confounding effects of sexual dimorphism and uneven sex distributions on the results, only male crania are used in this analysis (Table 2). Where associated pelves were present, skeletons were sexed through an assessment of pelvic and cranial morphology (Washburn, 1948; Krogman, 1955; Phenice, 1969). Unfortunately, the majority of the Melanesian crania were without associated postcrania, and sex determination had to be based on cranial morphology alone. This remains an unavoidable source of error that may have had an impact on statistical indicators of variation within the Arawe and Tolai samples. For broad comparison of the structural relationships in bivariate distributions, regression slopes, and standard errors, the Melanesian and Australian samples were also compared with bivariate distributions in the Howells global male sample ($n = 1368$; Howells, 1989, 1995). As Howells was concerned with the morphological relationships among recent human populations, as indicated by their cranial dimensions, he excluded intentionally modified crania in his sample. While the regional comparisons are

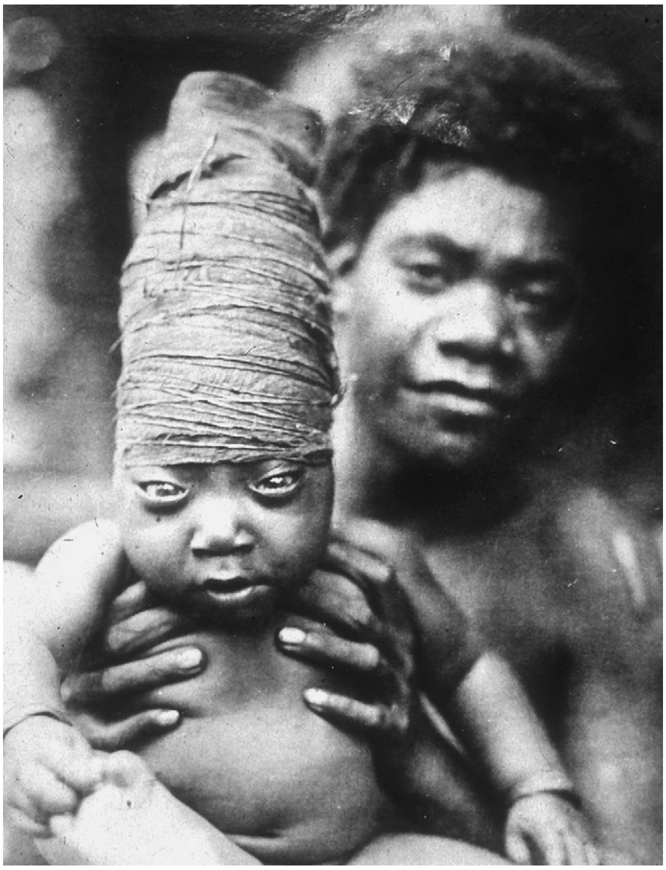

Figure 3. Arawe infant, with its head bound, and mother, south-west New Britain. Photographed by Beatrice Blackwood in 1937.

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

Table 2
Descriptive statistics for the cranial linear dimensions and subtenses in the four male *Homo sapiens* groups and Indonesian *H. erectus* used in the principal components and discriminant function analyses, the individual dimensions for Nacurrie 1, and angle statistics for the same groups.

Variable	Group	*N*	X	SD	CV	Nacurrie
Max. biparietal br.	TP	17	137.4	3.37	0.025	135.0
	LH	34	132.3	4.46	0.034	
	Tolai	65	130.6	3.85	0.030	
	Arawe	52	128.6	4.51	0.035	
	H. erectus	6	141.5	5.92	0.042	
Basion-bregma	TP	17	141.5	3.85	0.027	142.0
	LH	34	132.0	5.83	0.044	
	Tolai	65	135.5	4.38	0.032	
	Arawe	52	136.6	5.80	0.042	
	H. erectus	6	121.7	6.08	0.050	
Frontal chord	TP	17	121.1	6.64	0.055	138.0
	LH	34	112.9	4.14	0.037	
	Tolai	65	109.0	4.22	0.039	
	Arawe	52	117.1	5.33	0.046	
	H. erectus	6	112.3	1.86	0.017	
Frontal subt. h.	TP	17	23.4	3.79	0.162	20.0
	LH	34	25.6	2.25	0.088	
	Tolai	65	23.9	2.11	0.089	
	Arawe	52	19.0	3.18	0.167	
	H. erectus	6	19.8	1.32	0.067	
Parietal chord	TP	17	120.3	5.46	0.045	123.0
	LH	34	116.6	4.99	0.043	
	Tolai	65	116.7	4.76	0.041	
	Arawe	52	115.2	7.07	0.061	
	H. erectus	6	101.0	4.94	0.049	
Parietal subt. h.	TP	17	25.1	3.23	0.129	29.0
	LH	34	23.8	3.05	0.128	
	Tolai	65	25.9	2.69	0.104	
	Arawe	52	31.0	3.67	0.119	
	H. erectus	6	12.8	0.75	0.059	
Occipital chord	TP	17	100.9	4.64	0.046	108.0
	LH	34	93.2	4.31	0.046	
	Tolai	65	95.8	4.57	0.048	
	Arawe	52	99.4	5.62	0.057	
	H. erectus	6	86.3	4.54	0.053	
Occipital subt. h.	TP	17	28.4	3.22	0.113	27.0
	LH	34	27.9	3.07	0.110	
	Tolai	65	29.4	2.96	0.101	
	Arawe	52	22.2	3.99	0.180	
	H. erectus	6	38.8	2.31	0.060	
Frontal angle	TP	17	22.5	3.90	0.173	15.1
	LH	34	26.7	2.23	0.084	
	Tolai	65	25.6	2.53	0.099	
	Arawe	52	19.6	4.20	0.214	
	H. erectus	6	20.8	0.94	0.045	
Parietal angle	TP	17	21.6	2.83	0.131	25.8
	LH	34	21.3	1.66	0.078	
	Tolai	65	23.9	2.36	0.099	
	Arawe	52	27.2	2.67	0.098	
	H. erectus	6	15.3	3.78	0.246	
Occipital angle	TP	17	28.8	3.39	0.118	28.8
	LH	34	30.5	4.02	0.132	
	Tolai	65	32.1	3.22	0.100	
	Arawe	52	21.5	5.07	0.236	
	H. erectus	6	39.1	4.69	0.120	

most important, Howells' data are expected to provide a robust picture of the limits of normal human cranial vault size and shape.

A comparative, broadly recent Australian Aboriginal sample was provided by skeletons excavated from the Murray River region of south-eastern Australia (male = 47, female = 53) (Brown, 1989, 1992a,b). Previous morphological and metric comparisons between these skeletons, the mid-Holocene samples from Roonka (Pretty, 1977; Brown, 1989; Pate et al., 1998), Barham (Brown, 1989), and Wentworth (Blackwood and Simpson, 1973; Brown, 1989), and the terminal Pleistocene–early Holocene skeletons from the same region, have highlighted the significantly larger cranial, postcranial, and dental dimensions found in early (>7 ka) Australians (Pietrusewsky, 1971, 1984; Thorne and Macumber, 1972; Brown, 1989, 1992a,b). Given the morphological and metric similarity between the dated mid-Holocene skeletons and the recent series, and their shared morphological distinction from the majority of skeletons dated to >7 ka, I consider the comparative sample to be broadly late Holocene (LH, <7 ka) in age. The majority of the recent Australian crania had associated postcranial skeletons and sex determination was based on an assessment of pelvic and cranial morphology (Brown, 1981b, 1989). Crania without associated pelves were sexed using cranial morphology and linear discriminant functions developed from crania that could be independently sexed through their associated postcranial skeletons. As for the Melanesian sample, this remains a potential source of error in statistical comparisons. When recorded, these skeletons were located in the Department of Anatomy, University of Melbourne, but were subsequently returned to Aboriginal communities for reburial in 1984.

All of the terminal Pleistocene and early Holocene male crania from south-eastern Australia (TP, >7 ka), with adequate preservation, were used for comparison with Nacurrie, the two New Britain samples, and the late Holocene Aboriginal series (Table 3). Between 1984 and 1992, the Coobool Creek (CC), Kow Swamp (KS), and Nacurrie skeletons were repatriated to Aboriginal Communities for reburial (Mulvaney, 1991). Casts of the Nacurrie, KS, and Keilor crania are available in collections in the United States, UK, Japan, China, and Australia, with other data available at the University of New England and Australian National University. With the exception of the Howells' global *H. sapiens* sample (Howells, 1976, 1989, 1995), all of the *H. sapiens* measurements were recorded from the original skeletons by the author (Brown, 1987b, 1989). Chord, subtense, and angle measurements follow the definitions used by Howells (1976), and statistical comparison of Howells' Australian and Tolai samples with those collected by PB did not reveal significant differences in mean dimensions suggestive of systematic differences in measurement.

The comparative Indonesian *H. erectus* series consists of Ngandong 6, 7, 10, 11, and 12 (Weidenreich, 1951; Santa Luca, 1980), Sangiran 2 (von Koenigswald, 1940), 4 (Weidenreich, 1945), and 17 (Aziz et al., 1996), Sambungmacan 1 (Jacob, 1976), 3 (Marquez et al., 2000; Delson et al., 2001), and 4 (Baba et al., 2003), and Ngawi (Widianto and Zeitoun, 2003). Recently, Kaifu et al. (2008)

Table 3
The terminal Pleistocene–early Holocene male skeletal sample from south-eastern Australia used in morphological and metric comparisons where preservation was adequate.

Location	Specimen numbers	References
Coobool Creek	5, 8, 10, 13, 16, 23, 28, 29, 32, 35, 36, 37, 41, 45, 46, 49, 51, 65, 66, 71, 76, 82	Brown, 1989
Kow Swamp	1, 3, 5, 7, 8, 9, 14, 15, 17, F9	Thorne, 1975; Brown, 1989
Willandra Lakes	3, 19, 50	Bowler and Thorne, 1976; Caddie et al., 1987; Webb, 1989; Stringer, 1998; Simpson and Grun, 1998
Nacurrie	1, 2	Brown, 1994a; Webb, 1995
Keilor		Wunderly, 1943; Brown, 1989
Cohuna		Macintosh, 1952a,b; Macumber and Thorne, 1975; Brown, 1989
Mossgiel		Freedman, 1986
Lake Tandou		Freedman and Lofgren, 1983
Lake Nitchie		Macintosh, 1971; Brown, 1989

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

presented a detailed comparison of the Javan *H. erectus* sample, with a discussion of preservation and previously recorded measurements. All chord dimensions used in this study were ±2 mm of those recorded by Kaifu et al. (2008) and within the range of those recorded by previous authors (Santa Luca, 1980; Rightmire, 1990). Postmortem damage to the basicranium and anterior portions of the frontal bone of many of the *H. erectus* calvaria limited the sample ($n = 6$) for multivariate statistical comparisons. For specimens with minimal damage to glabella, and the posterior margin of the foramen magnum, landmarks (nasion and opisthion) were reconstructed on casts by estimating the location of the feature through reference to adjacent structures, with an expected error of ±3 mm suggested by an examination of inter-observer error. Measurements on casts were adjusted for shrinkage through reference to the original specimens or data in Kaifu et al. (2008).

Postmortem damage, particularly to the cranial base and facial skeleton, reduced the number of crania available for multivariate analyses, particularly with the TP Australians (TP 42/17, LH 47/34, Tolai 67/65, Arawe 55/52, *H. erectus* 13/6). Focusing on a limited number of vault dimensions maximised sample size, but the two most complete Kow Swamp (KS1 and 5; Thorne and Macumber, 1972) and Wilandra Lakes crania (LM3, WLH50; Bowler and Thorne, 1976; Stringer, 1998) could only be included in morphological and bivariate comparisons.

Measurements and statistical procedures

Measurements were restricted to those that previous sources indicated could be useful in distinguishing between the vault shapes of intentionally modified and unmodified Melanesian and Australian crania (Blackwood and Danby, 1955; Brothwell, 1975; Brown, 1981a, 1989; Antón, 1989; Cybulski, 1989; Kiszely, 1989; Antón and Weinstein, 1999), and had been previously recorded on Nacurrie and the majority of the crania in the comparative groups. The repatriation of a large part of the Australian sample in the 1980s limited this study to existing data and precluded the application of either three-dimensional geometric morphometrics (O'Higgins and Jones, 1998), or elliptic Fourier analysis of vault contours (Lestrel, 1997): methods which have proven successful in distinguishing differences in calvarial shape associated with intentional modification (Friess and Baylac, 2003; Perez, 2007). For the multivariate comparisons, five linear dimensions and three subtenses were recorded on the cranial vaults with sliding, coordinate, and spreading calipers, using the procedures and definitions described by Martin and Saller (1957) and Howells (1973) (Table 2). Frontal curvature (FCI) and parietal curvature (PCI) indices (subtense * 100/chord) have proved useful in distinguishing between modified and unmodified crania (Brown, 1989) and were measured and calculated using the procedures defined by Larnach (1974) and Brown (1989).

A variety of exploratory procedures were employed to examine sample-based differences in the distributions of data used in this analysis. These procedures were first applied to the Arawe and Tolai and then extended to all of the other samples. The distribution of all data sets were examined graphically using normal probability, stem and leaf, and boxplots, and distributions tested for univariate normality with the Shapiro–Wilk and Kolmogorov–Smirnov tests ($p < 0.01$). Bivariate associations were examined using scatterplots, least-squares regression, and plots of residuals, with ANCOVA to test for differences in regression slopes and y-intercepts. Where there were more than two groups, significant differences in mean size and shape (proportions) were tested using one-way analysis of variance (ANOVA), with Bonferroni adjustment to protect against the Type I errors associated with multiple pairwise comparisons. Results were considered statistically significant at $p < 0.05$.

The extent and pattern of multivariate differentiation between groups, classification probabilities, and the influence of individual variables on distributions, were explored using principal components analysis (PCA) and discriminant function analysis (DFA), with eight cranial dimensions (Table 2). PCA uses a single set of variables to discover if any of the variables form subsets (groups) that are relatively independent of each other. The factors generated by the PCA are based on correlated, as well as inversely correlated, subsets of variables, which may reflect underlying biological processes (Jackson, 1991; Chase et al., 2002). The primary purpose of DFA is to predict group membership from a set of predictors. DFA assumes that groups are correctly identified and the final solution will maximise between-group variance, while minimising within-group variance. The loading matrix of correlations between predictors and discriminant functions provides information on the relative contribution of predictors to group membership (Tabachnick and Fidell, 2001). Terminal Pleistocene–early Holocene Australians had skeletons and crania that were significantly larger than recent populations living in the same geographic region (Brown, 1987b, 1989, 1992b). Therefore, in order to employ metric data to examine population-based differences in cranial vault shape it was necessary to adjust for the potentially confounding influence of body size. To examine the influence of size on distributions, separate PCAs and DFAs were performed, using size-adjusted and unadjusted raw data; size adjustment was accomplished by dividing each specimen value by the geometric mean of the specimen's values (Jungers et al., 1995; Ackermann, 2002, 2005; Lycett and Collard, 2005). This ratio-based size adjustment follows Darroch and Mosimann (Mosimann and James, 1979; Darroch and Mosimann, 1985) and creates new scale-free shape variables, which remove isometric size but not size-related (allometric) shape (Ackermann, 2005; von Cramon-Taubadel et al., 2005). Statistical and graphical procedures were performed using SYSTAT 13 and PASW Statistics 18.

Results

Univariate and morphological comparisons

Although there is considerable variation within the Arawe sample, these individuals can be easily distinguished from the Tolai by the morphology, size, and curvature of their frontal, parietal, and occipital bones (Brown, 1981a, 1989). The Arawe frontal bones are receding, often convex rather than concave in their middle third, and have associated bilateral depressions in the mid-frontal squama. A pre-bregmatic eminence is common, and lateral X-rays indicate that this is a result of the expansion of the diploë in the posterior frontal (Figs. 4 and 5). However, in the mid-frontal squama the diploë is often constricted. None of these features were present in the Tolai frontal bones (Brown, 1989). The development of the supraorbital region, including projection of glabella and presence of a supratoral sulcus, was similar in both samples. The Arawe often have a distinctive parietal saddle (a broad depression, variable in length and depth, running from one parietal to the other, across the sagittal suture, and slightly posterior to the coronal suture, Fig. 5) and prominent parietal eminences, but the Tolai did not. None of the Arawe or Tolai crania had a supraorbital torus, supratoral sulcus, bregmatic or T-eminence, or coronal ridge on the parietals. Some of the Tolai had a slight metopic ridge in the middle third of the frontal squama, which was not present in the Arawe.

Comparison of the unadjusted means indicate that the Arawe have significantly longer and flatter frontal bones (longer frontal chord and shorter subtense height), greater curvature of the

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

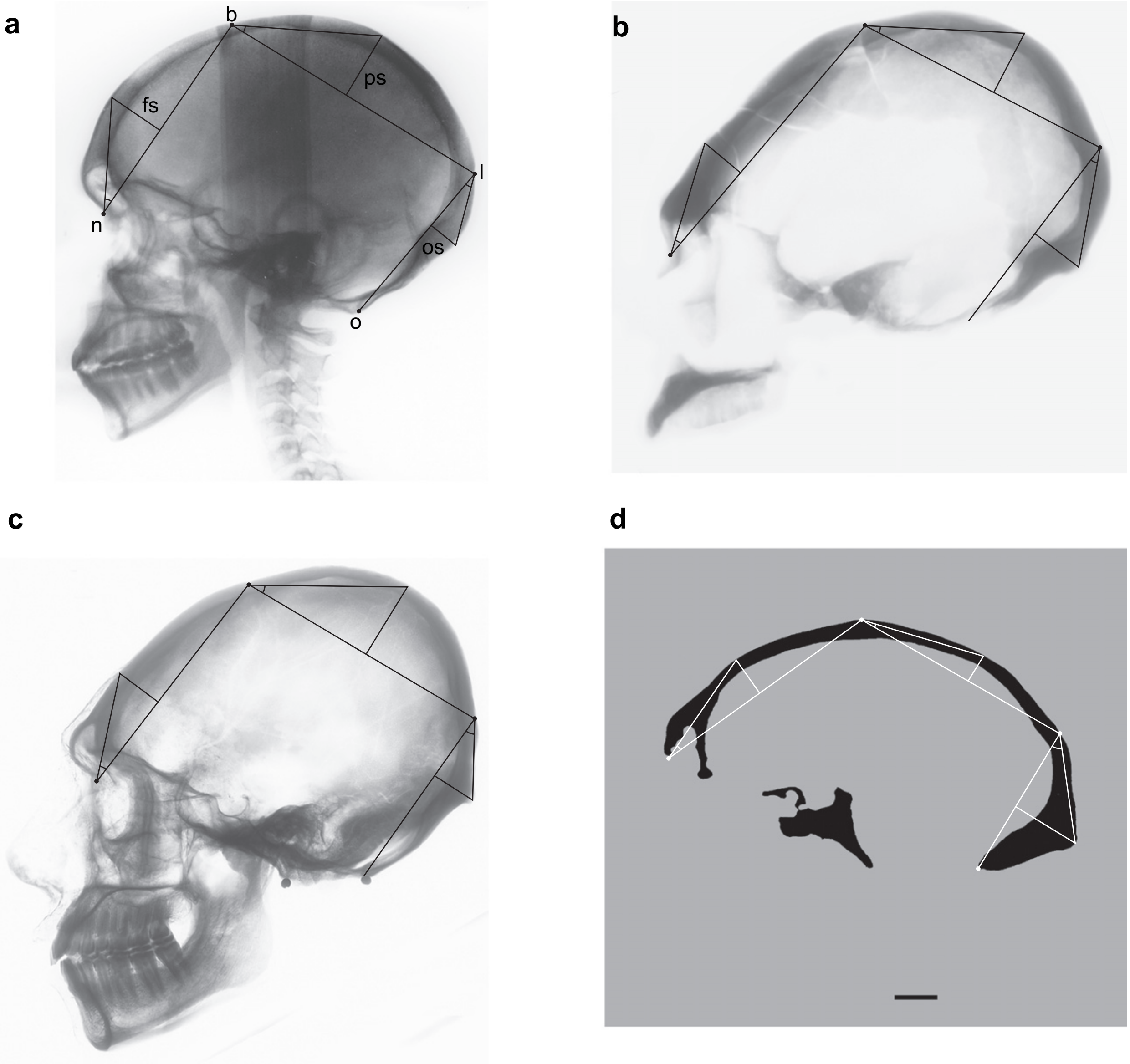

Figure 4. Lateral radiographs of *H. sapiens* and sagittal CT scan of *H. erectus*; (a) Australian Aborigine, (b) Nacurrie 1, (c) Arawe, and (d) a mid-sagittal section of the Sambungmacan 4 *H. erectus* redrawn from a CT scan in Baba et al. (2003).

parietals (larger subtense height), and longer and flatter occipital bones (longer occipital chord and shorter subtense height) than the Tolai (Tables 2 and 5). With the size-adjusted data, the differences in the occipital chord are no longer significant, and the greater mean cranial height (basion-bregma) of the Arawe becomes significant (Table 6). Shape differences associated with modification are preserved in size-adjusted data, with the significance of differences in the three subtense dimensions retained. With the exception of parietal angle, coefficients of variation (CV) are all larger in the Arawe than in the Tolai (Table 2).

There is a greater variation in the TP Australians than in the LH sample, and this is reflected both metrically and in the expression of their morphology (Tables 2 and 4). Average projection of glabella and depression of nasion were more developed in the LH and, with a very small number of exceptions (Brown, 1989), true supraorbital tori without clearly separated glabella, superciliary ridges, and zygomatic trigones, were not present in either sample. There were no supratoral sulci and low metopic ridges were common in male crania from both samples. All of the LH Australians had a convex supraorbital plane, while five of the TP Australian group had a receding, flat, and somewhat concave mid-frontal. Bilateral frontal depressions and a pre-bregmatic eminence, similar to those in the Arawe, were present in the early group, e.g., KS5, CC65, and Nacurrie 1, but not in crania with a high frontal angle and convex midline frontal profile (Figs. 2, 4, and 6). Midline cranial vault thickness, measured directly and with standardized lateral radiographs (Brown, 1987a, 1989), indicated that while the majority of the TP Australian sample had the uniformly thick frontals typical of Australian Aboriginal populations, some did not (Brown et al., 1979; Brown, 1994b). Lateral radiographs show that, similar to the Arawe, pre-bregmatic eminences were the result of expanded diploë, with flat to concave frontal profiles, and constricted diploë in the middle third of the frontal squama (Figs. 4–6). A small percentage of both Australian groups had a low bregmatic eminence, but a T-eminence and coronal ridge, as in some Indonesian *H. erectus* (Santa Luca, 1980), was not present. None of the LH Australian crania had a parietal saddle, but a slight saddle (not as deep as in some of the Arawe) was present in several of the Coobool Creek crania (Brown, 1989) and

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

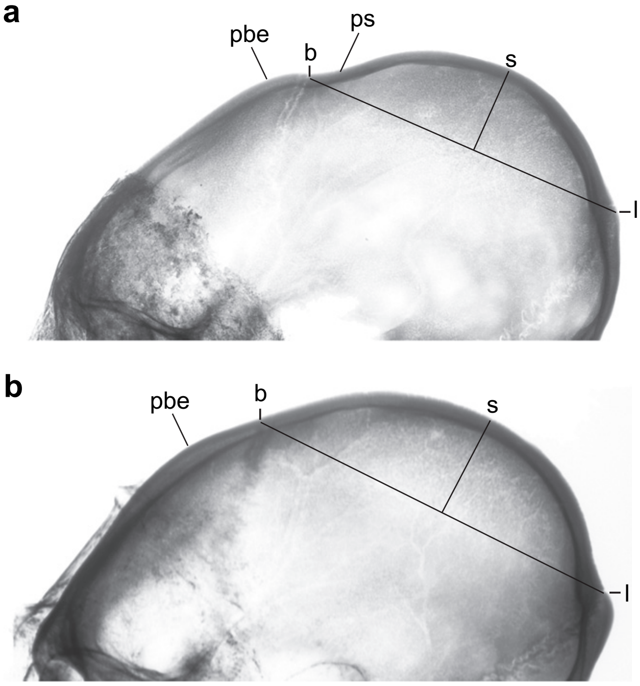

Figure 5. Lateral radiographs of two male Arawe crania showing variation in vault contours and vault bone thickness: pbe (pre-bregmatic eminence); b (bregma); ps (parietal saddle); s (parietal subtense), and l (lambda).

Nacurrie. Parietal eminences, usually poorly expressed, or absent, in Aboriginal male crania (Larnach and Macintosh, 1966; Larnach, 1976), were relatively well developed in several of the TP Australian sample with low frontal angles, including KS5 and Nacurrie (Brown, 1989).

The ANOVA results and descriptive statistics highlight the significantly larger mean dimensions of the TP crania when compared with their LH counterparts (Brown, 1987b, 1989) (Tables 2, 4, and 5). Average cranial height, biparietal breadth, and frontal and occipital chord dimensions are significantly larger in the TP Australian group. However, in the unadjusted data, frontal subtense height is significantly greater in the LH Australians, and there are no significant differences in the mean parietal and occipital subtense heights (Table 4). This is surprising, as subtense height, particularly in the frontal bone, should increase proportionally with the length of the chord (Young, 1957) (Figs. 2 and 4). With the size-adjusted data, the differences in mean parietal breadths are no longer significant, but the large occipital subtense heights of the TP Australian group become significant (Table 5). With the exception of maximum biparietal breadth, cranial height, and occipital angle, CVs are all greater in the TP Australian group than in the LH series (Table 2).

Table 4
Results of pairwise comparisons for statistical differences in mean linear dimensions between the five groups used in the multivariate analyses (1: TP; 2: LH; 3: Tolai; 4: Arawe; 5: *H. erectus*)[a].

	1/2	1/3	1/4	1/5	2/3	2/4	2/5	3/4	3/5	4/5
Max biparietal br.	*	*	*	NS	NS	*	*	NS	*	*
Basion-bregma	*	*	*	*	*	*	*	NS	*	*
Frontal chord	*	*	*	*	*	*	NS	*	NS	NS
Frontal subt. h.	*	NS	*	NS	*	*	*	*	*	NS
Parietal chord	NS	NS	*	*	NS	NS	*	NS	*	*
Parietal subt. h.	NS	NS	*	*	*	*	*	*	*	*
Occipital chord	*	*	NS	*	NS	*	*	*	*	*
Occipital subt. h.	NS	NS	*	*	NS	*	*	*	*	*

*$p < 0.05$; NS, not significant.
[a] Bonferroni-adjusted, one-way ANOVA.

Table 5
Results of pairwise comparisons for statistical differences in size-adjusted mean linear dimensions between the five groups used in the multivariate analyses (1: TP; 2: LH; 3: Tolai; 4: Arawe; 5: *H. erectus*)[a].

	1/2	1/3	1/4	1/5	2/3	2/4	2/5	3/4	3/5	4/5
Max biparietal br.	NS	*	NS	*	*	NS	*	NS	*	*
Basion-bregma	*	NS	NS	NS	NS	*	NS	*	NS	NS
Frontal chord	*	*	NS	*	*	NS	*	*	*	NS
Frontal subt. h.	*	NS	*	NS	*	*	*	*	NS	NS
Parietal chord	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Parietal subt. h.	NS	NS	*	*	*	*	NS	*	*	*
Occipital chord	*	NS	NS	NS	NS	*	NS	NS	NS	*
Occipital sub. h.	*	*	NS	NS	*	NS	NS	*	*	*

*$p < 0.05$; NS, not significant.
[a] Bonferroni-adjusted, one-way ANOVA.

Not surprisingly, Indonesian *H. erectus* is morphologically and metrically distinct from the unmodified and modified Australian and Melanesian *H. sapiens*. All of the Indonesian calvaria have true supraorbital tori, with the thickest point of the torus usually on the lateral frontal near the zygomatic trigone (Santa Luca, 1980), not somewhere between glabella and mid-orbit as in *H. sapiens*. Supratoral sulci are present in some of the Ngandong and Sangiran crania and may be particularly deep posterior to the zygomatic trigones, but, in others, the sulcus is shallow and vanishes towards the midline (Santa Luca, 1980). A low metopic ridge is present in most of the frontals where the frontal squama is well-preserved. Frontal bones are receding but convex, with a lower frontal angle than in unmodified *H. sapiens*. Frontal bosses are usually low or absent (Sangiran 17), but may be reasonably prominent, as in Sambungmacan 3. The *H. erectus* frontals have neither the mid-frontal depressions nor pre-bregmatic eminence evident in the Arawe and some of the TP Australians. At the midline, cranial vault thickness increases gradually towards the posterior frontal and without the mid-frontal constriction of the diploë present in the Arawe, KS5, and some of the CC crania (Brown, 1989, 1994b; Baba

Table 6
Results of the pairwise significance tests for differences in slopes or y-intercepts for the relationship between chord and subtense dimensions, and indices in the *H. sapiens* and *H. erectus* groups[a,b].

Group	LH	Tolai	Arawe	*H. erectus*
Frontal subtense and chord				
TP	*/*	*/*	NS/NS	NS/NS
LH		NS/NS	*/*	NS/NS
Tolai			*/*	NS/NS
Arawe				NS/NS
Parietal subtense and chord				
TP	NS/NS	NS/NS	*/NS	*/NS
LH		NS/NS	NS/*	NS/NS
Tolai			NS/NS	NS/NS
Arawe				NS/NS
Occipital subtense and chord				
TP	*/*	*/*	NS/NS	NS/NS
LH		NS/NS	*/*	NS/NS
Tolai			*/*	NS/NS
Arawe				NS/NS
PCI and FCI				
TP	NS/*	*/*	NS/*	*/NS
LH		NS/NS	*/*	NS/NS
Tolai			*/*	NS/NS
Arawe				NS/NS

*$p < 0.05$; NS, not significant
[a] Statistical significance and identification of outliers was influenced by whether the chord or subtense dimension was the dependent variable. The results of significance tests for both are provided, with subtense as the dependent variable listed first.
[b] Statistical significance was influenced by whether PCI or FCI was the dependent variable. The results of significance tests for both are provided, with PCI as the dependent variable listed first.

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

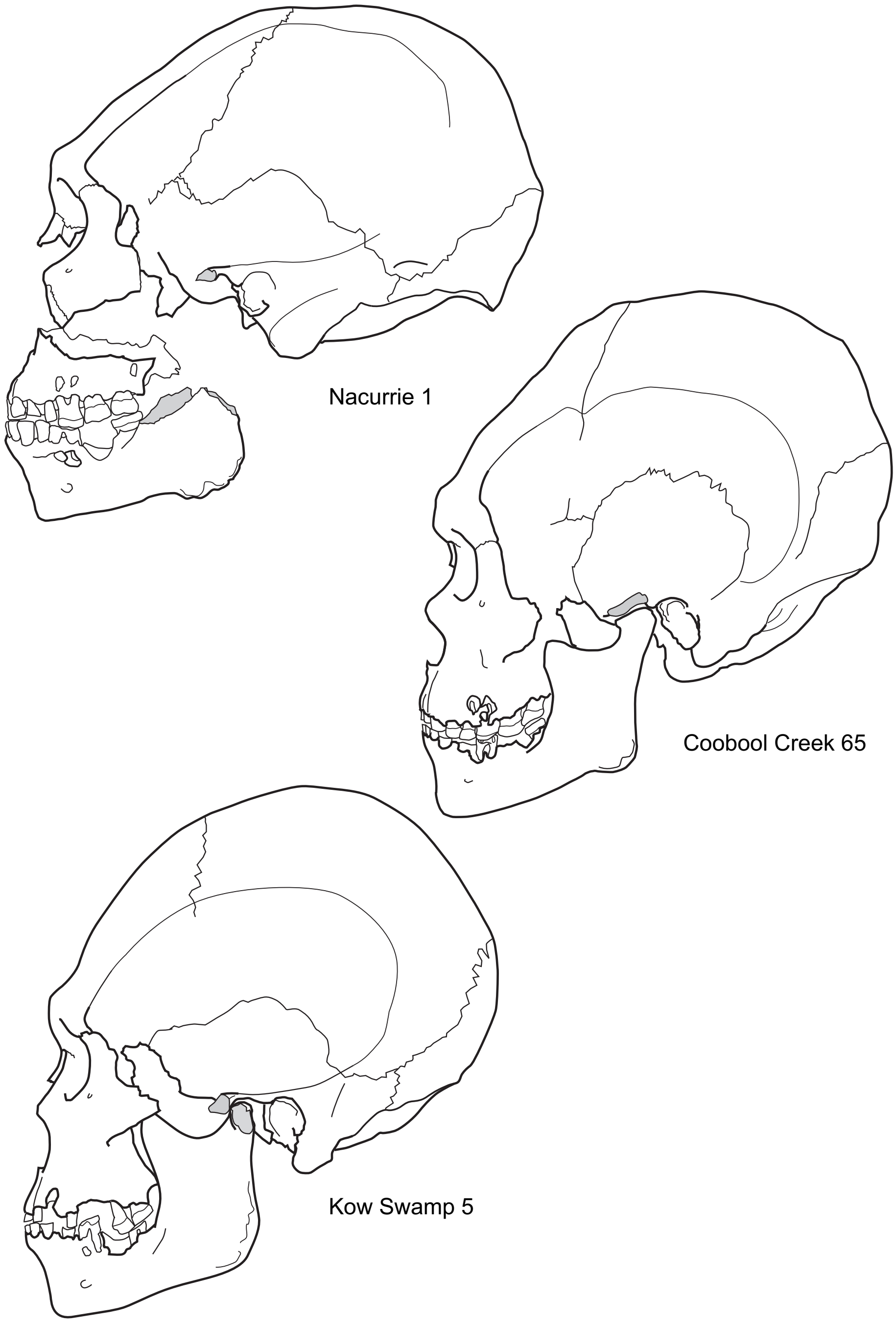

Figure 6. Left lateral views of terminal Pleistocene crania from south-eastern Australia: Nacurrie 1, Kow Swamp 5, and Coobool Creek 65.

et al., 2003) (Fig. 4). Most of the Indonesian crania have a slight-to-moderate bregmatic eminence, T-eminence (Weidenreich, 1951; Santa Luca, 1980), and coronal ridge. Anteriorly, the coronal ridge is usually bracketed by shallow parasagittal depressions, which accentuate the prominence of the ridge. Viewed laterally, the parietal bones have much less curvature than in *H. sapiens*, and parietal eminences are not present in the mid-parietal region.

In the unadjusted ANOVA, the *H. erectus* calvaria have significantly lower cranial heights, shorter parietal and occipital chords, lower parietal subtense heights, and higher occipital subtense heights than *H. sapiens* (Table 4). Parietal bones are flatter in sagittal section, and occipital bones are much more highly angled. This is a complete contrast with the modified Arawe where antero-posterior pressure during infancy flattens the frontal and occipital regions, and increases the curvature of the parietals. With size-adjusted data, the significance of many of the pairwise mean comparisons with *H. erectus* are removed. Greater average biparietal breadth in *H. erectus* remains significant, but the lower cranial height loses its significance and the importance of occipital curvature (subtense height) is reduced (Table 6). The Arawe mimic *H. erectus* in their low frontal subtense heights, but not in the dimensions of their parietals and occipital bones.

Nacurrie has many of the morphological features common to the Arawe that make them distinct from both the Tolai and Indonesian *H. erectus* (Table 2, Figs. 2, 4, and 6). Nacurrie lacks a supraorbital torus, with complete separation of the supraorbital elements.

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

Maximum supraorbital thickness is on the superciliary ridges, approximately 21 mm from the midline. The frontal squama is receding, without a supratoral sulcus, and slightly concave mid-frontal (Figs. 2, 4, and 6). There is a low metopic ridge bordered by bilateral mid-frontal depressions, and no frontal bossing. The median ridge is continuous with a prominent pre-bregmatic eminence, which results from greatly expanded diploë (Figs. 2 and 4). The diploë constricts mid-frontal as in many of the Arawe. There is no T-eminence or coronal ridge, and a shallow parietal saddle crosses the sagittal suture adjacent to the coronal suture. Bilaterally, the parietal eminences are prominent. Linear dimensions emphasize the great size of Nacurrie in comparison to the late Holocene means. The frontal bone is particularly elongated with a low subtense height, and frontal angle below the Arawe and *H. erectus* means. The parietal angle is relatively high, within one standard deviation of the Arawe mean, and contrast with the extremely low parietal angle in *H. erectus* (Fig. 4)

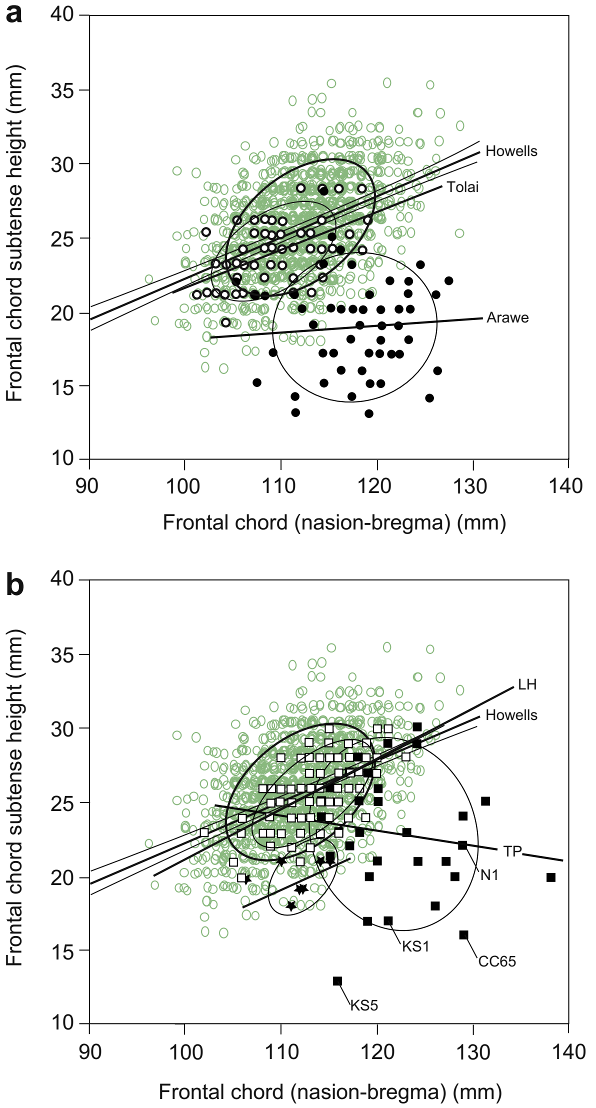

Figure 7. Scatterplots of the association between frontal chord and frontal subtense height: (a) Tolai (circles), Arawe (filled circles), and Howells' global series (green circles); (b) LH (squares), TP (black squares), Indonesian *H. erectus* (stars), and Howells' global series (green circles). Ordinary least-squares regression lines, sample confidence ellipses ($p > 0.68$), and confidence bands ($p > 0.95$) for the Howells series. The sample confidence ellipse for the Howells series has a heavier line weight. Individual specimens: Nacurrie (N1), Coobool Creek (CC65), Kow Swamp (KS1, KS5). Howells' global series: $n = 1368$, $r = 0.45$, SE = 2.71, $y = -5.564 + 0.277\times$; Tolai: $n = 65$, $r = 0.50$, SE = 1.844, $y = -3.475 + 0.251\times$; Arawe: $n = 55$, $r = 0.07$, SE = 3.237, $y = 13.754 + 0.043\times$; LH: $n = 93$, $r = 0.624$, SE = 1.738, $y = -12.665 + 0.338\times$; TP: $n = 32$, $r = 0.153$, SE=4.065, $y = 35.957 \pm 0.108\times$; Indonesian *H. erectus*: $n = 6$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Bivariate comparisons

In the human frontal bone there is a positive, and reasonably linear, association between the length of the frontal chord and the height of the frontal subtense. As the length of one increases, so does the other (Howells' data: $r = 0.45$, SE = 2.71; Tolai: $r = 0.50$, SE = 1.84; late Holocene Australians: $r = 0.62$, SE = 1.73) (Fig. 7). The OLS regression slopes for the association between frontal chord length and frontal subtense height in the Tolai and LH Australians are approximately parallel with Howells' global sample, and 60% confidence ellipses strongly overlap. This is in marked contrast to the Arawe distribution where the usual positive allometry between frontal bone length and frontal subtense height is not present (Arawe: $r = 0.07$, SE = 3.27), with significant differences in OLS regression slopes between the Arawe, and the Tolai and LH samples (Table 6). The Arawe distribution is distinct from the unmodified Tolai, and there is much greater variation in the association of these measures of frontal curvature. In the Arawe the average length of the frontal chord has increased but the height of the frontal subtense has decreased. As the profile of the bone has been flattened, there is a closer correspondence between the arc and chord length of the bone. The location of metopion, the point of maximum height (curvature) above the chord, moves anteriorly, and some frontals have a concave rather than convex mid-frontal lateral profile (Fig. 4).

The LH Australian series shares the relationship between frontal chord and frontal subtense height that is present in the Tolai, and Howells' global sample (Fig. 7, Table 6). This contrasts with the TP Australians, where there is much greater dispersion and the usual allometric association between frontal bone length and curvature is not present in some of crania. OLS regression slopes in the LH and TP Australians are significantly different (Table 6). However, the distributions of the Arawe and TP Australians overlap, and their OLS regression slopes are similar, highlighting gross similarities in frontal morphology that distinguish them from unmodified crania (Table 6). Two of the TP Australians, Nacurrie and KS5, were identified as outliers with large studentized residuals (Nacurrie: −4.58 frontal cord, KS5: 4.37 frontal subtense height) (Fig. 7). Indonesian *H. erectus* frontal bones have less curvature in the sagittal plane than *H. sapiens* and are also distinct from TP Australians, including KS1, KS5, CC65, and Nacurrie 1.

With the exception of the Arawe ($r = 0.33$, SE = 3.50), all of the *H. sapiens* samples have a reasonably linear association between parietal chord length and parietal subtense height (Howells' data: $r = 0.66$, SE = 2.16; Tolai: $r = 0.59$, SE = 2.15; TP Australians: $r = 0.75$, SE = 2.22; LH Australians: $r = 0.62$, SE = 2.08) (Fig. 8). Antero-posterior constriction of the Arawe neurocranium during infancy greatly increases the curvature of the parietals in the sagittal plane, with associated greater subtense height. There is greater variation in Arawe parietal morphology than in the unmodified comparative samples and minimal overlap with the distributions of the other *H. sapiens* groups. Amongst the TP Australians, KS5, CC65, and N1 have the greatest parietal curvature (Fig. 8). Indonesian *H. erectus* parietals have minimal antero-posterior curvature and are distinct from TP Australians, including KS1, KS5, CC65, and N1. Differences between the OLS regression slopes of the Arawe and the TP (parietal subtense as the dependent variable) and LH (parietal chord as the dependent variable) indicate that Australians are significant (Table 6).

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

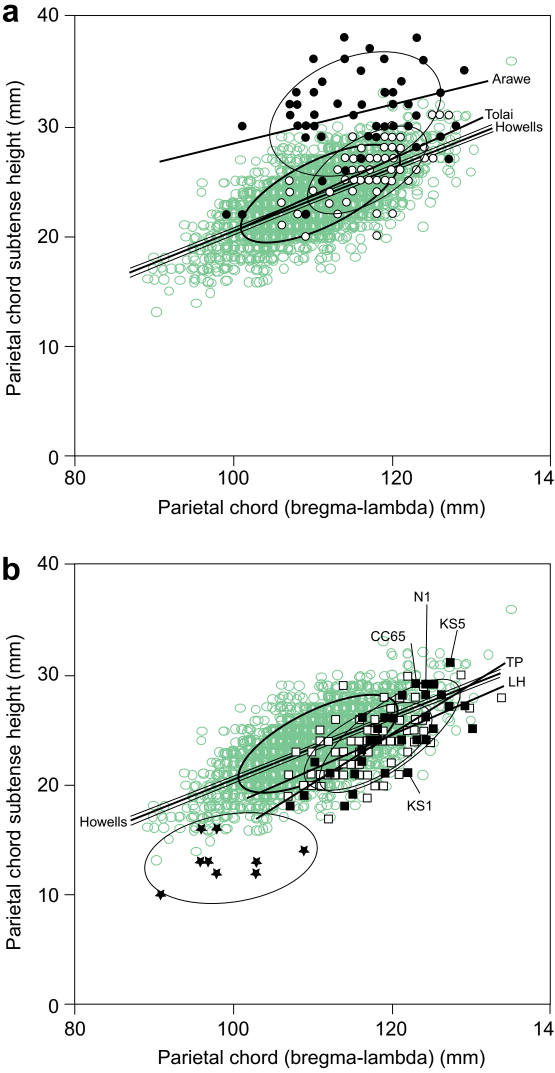

Figure 8. Scatterplots of the association between parietal chord and parietal subtense height: (a) Tolai (circles), Arawe (filled circles), and Howells' global series (green circles); (b) LH (squares), TP (black squares), Indonesian *H. erectus* (stars), and Howells' global series (green circles). Ordinary least-squares regression lines, sample confidence ellipses ($p > 0.68$), and confidence bands ($p > 0.95$) for the Howells' series. The sample confidence ellipse for the Howells series has a heavier line weight. Individual specimens: Nacurrie (N1), Coobool Creek (CC65), Kow Swamp (KS1, KS5). Howells global series: $n = 2523$, $r = 0.66$, SE = 2.16, $y = -8.483 + 0.290\times$; Tolai: $n = 67$, $r = 0.59$, SE = 2.15, $y = -12.591 + 0.330\times$; Arawe: $n = 55$, $r = 0.33$, SE = 3.507, $y = 10.8684 + 0.175\times$; LH: $n = 82$, $r = 0.62$, SE = 2.08, $y = -13.585 + 0.317\times$; TP: $n = 35$, $r = 0.75$, SE = 2.22, $y = -29.384 + 0.449\times$; Indonesian *H. erectus*: $n = 8$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

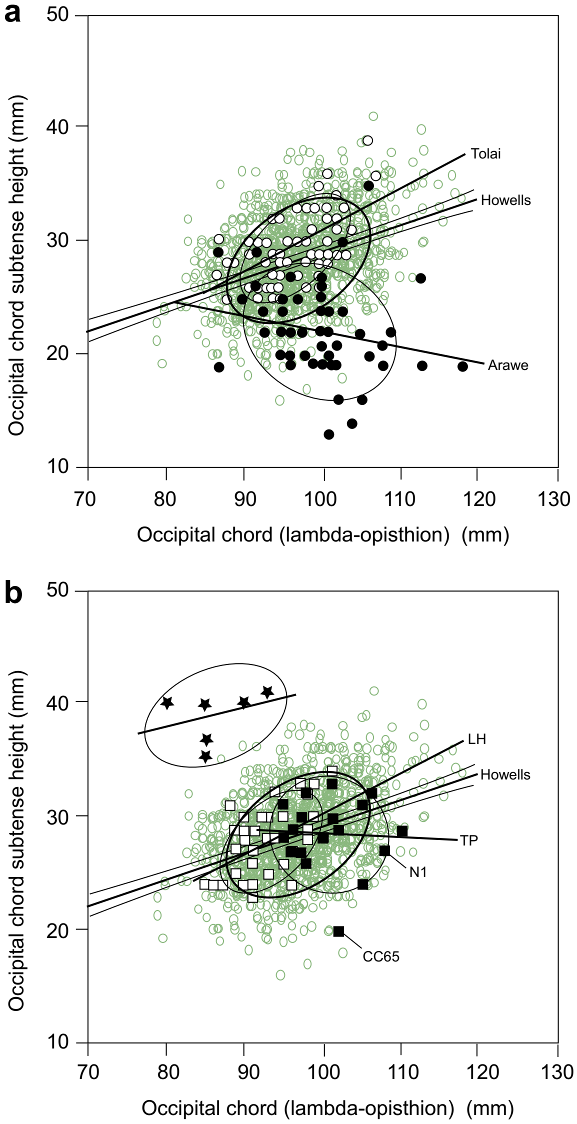

Figure 9. Scatterplots of the association between occipital chord and occipital subtense height: (a) Tolai (circles), Arawe (filled circles) and Howells' global series (green circles); (b) LH (squares), TP (black squares), Indonesian *H. erectus* (stars), and Howells' global series (green circles). Ordinary least-squares regression lines, sample confidence ellipses ($p > 0.68$), and confidence bands ($p > 0.95$) for the Howells series. The sample confidence ellipse for the Howells' series has a heavier line weight. Individual specimens: Nacurrie (N1), Coobool Creek (CC65). Howells global series: $n = 1368$, $r = 0.39$, SE = 3.34, $y = -5.510 + 0.235\times$; Tolai: $n = 67$, $r = 0.57$, SE = 2.44, $y = -6.231 + 0.372\times$; Arawe: $n = 55$, $r = 0.20$, SE = 3.88, $y = 35.478 \times 0.134\times$; LH: $n = 41$, $r = 0.49$, SE = 2.55, $y = -5.201 + 0.354\times$; TP: $n = 18$, $r = 0.05$, SE = 3.24, $y = 32.410 \pm 0.372\times$; Indonesian *H. erectus*: $n = 6$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

In the unmodified *H. sapiens* samples, broad linear relationships exist between the chord length of the occipital bone and its subtense height (Howells' data: $r = 0.39$, SE = 3.34; Tolai: $r = 0.57$ SE = 2.44; LH Australians: $r = 0.49$, SE = 2.55), and the OLS regression slopes of the LH Australians and Tolai are statistically similar (Table 6, Fig. 9). However, there is greater variation than in frontal curvature and this may result from the impact of nuchal muscle development and behaviour on the prominence of the occipital torus and subtense height. The Tolai confidence ellipse ($p > 0.64$) is within the ellipse for Howells' global series, although with a steeper regression slope resulting from greater projection of the subtense fraction in the Tolai. This contrasts with the Arawe occipitals that are relatively flat in the sagittal plane, with minimal projection of the occipital subtense and a negative correlation between the chord and subtense dimensions. The majority of the TP Australians have bivariate occipital dimensions within the normal human range. Four of the TP Australian crania have relatively flattened occipitals, with CC65 identified as an outlier (studentized residual = −3.44 for occipital subtense height) (Fig. 9). The OLS regression slopes of the TP Australians are significantly different from the unmodified *H. sapiens* samples, but this is primarily due to the leverage of CC65 (Table 6, Fig. 9). Indonesian *H. erectus* are distinguished by the angulation of the inferior and superior occipital scales, prominent occipital tori, and great subtense height in relation to chord lengths. Their bivariate occipital

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

dimensions (curvature) are distinct from TP and LH Australians, including Nacurrie 1 and CC65. Postmortem damage (KS5) and severe distortion (KS1) excluded the Kow Swamp crania from this bivariate comparison.

Comparison of the parietal curvature (PCI) and frontal curvature (FCI) indices of the *H. sapiens* groups highlights morphological differences between the TP and Arawe (Table 6, Fig. 10). In the LH Australians and Tolai, the correlations between PCI and FCI are extremely weak, with a slightly positive trend to their OLS regression slopes (LH: $n = 34$, $r = 0.02$, $y = 19.56 + 0.022\times$; Tolai: $n = 67$, $r = 0.081$, $y = 20.41 + 0.082\times$). This contrasts with the strong negative correlation and inverse slope in the Arawe, where flatter frontal bones are associated with greater curvature in the parietals ($n = 55$, $r = 0.51$, $y = 36.019 - 0.56\times$) (Fig. 10). In the TP Australians, there is also a high correlation between PCI and FCI and a negative OLS slope, but unlike the Arawe, PCI values remain within the LH and Tolai range of variation (TP: $n = 31$, $r = 0.56$, $y = 26.81 - 0.335\times$) (Fig. 10). ANCOVA indicates that differences between OLS slopes of the Arawe and unmodified *H. sapiens* (LH and Tolai), TP and Tolai, and TP and Arawe were all significant (Table 6). One of the TP Australians, KS1, was an outlier (studentized residual: −3.33) with undue influence on the correlation coefficient and OLS slope. There is some evidence of postmortem distortion in KS1, which may have influenced its PCI and FCI scores (Brown, 1989).

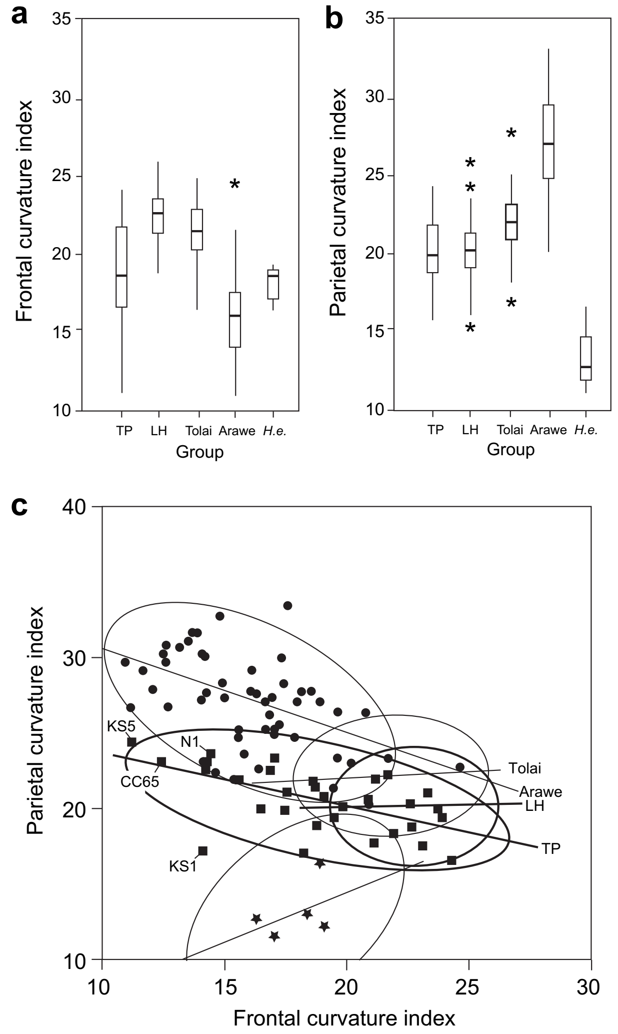

Figure 10. Boxplots and scatterplot of the association between PCI and FCI in the *H. sapiens* and *H. erectus* samples: (a) boxplot of the distribution of FCI scores, (b) boxplot of the distribution of PCI scores, (c) scatterplot of the association between PCI and FCI. Arawe (filled circles), TP (filled squares), and Indonesian *H. erectus* (stars). Ordinary least-squares regression lines, sample confidence ellipses ($p > 0.90$).

Multivariate comparisons

Discriminant function analysis (DFA) was performed for the *H. sapiens* and *H. erectus* raw data using eight variables as predictors of membership in the five groups (Tables 7–10). The analysis included 174 cases, and none were identified as multivariate outliers with $p < 0.001$. Evaluation of statistical assumptions of linearity, normality, and homogeneity of variance–covariance matrices indicated a robust analysis. However, as there are also only six *H. erectus* crania, there are too few cases to be non-singular in tests of the null hypothesis of equal population covariance matrices. Four discriminant functions were calculated with $\chi^2 = 538.0$, $p = 0.000$ (53.1% variance). There was still a strong association between groups and predictors after the removal of the first function, with $\chi^2 = 300.3$, $p = 0.000$ (31.3% variance), and the third and fourth functions were also significant (Function 3: $\chi^2 = 125.0$, 10.6%, $p = 0.000$; Function 4: $\chi^2 = 43.4$, 5%, $p = 0.000$). The loading matrix of correlations between predictors and discriminant functions indicated that for the first function the best predictors for distinguishing between the groups are parietal subtense height and occipital subtense height (Table 7). For the second function, the strongest predictors are frontal subtense height and the length of the frontal chord.

A plot of the function scores illustrates the ability of the variables to discriminate *H. erectus* from the modified and unmodified *H. sapiens* samples, the Arawe from the other *H. sapiens* samples, and to a lesser degree, the TP Australian crania from the unmodified *H. sapiens* (Fig. 11). The greatest overlap is in the distributions of the LH Australian and Tolai samples, which is reflected in the group classification results, and Mahalanobis (D^2) distances between group centroids (Tables 8–10). The distance between the Arawe and Tolai group centroids is greater than the difference between the two Australian Aboriginal samples. Classification probabilities for the highest group did not misclassify any of the TP Australian sample as Arawe, but a small number of Arawe were misclassified to each of the other *H. sapiens* samples (Table 8). Group classification results for the second most probable group allocated five of the TP Australians to the Arawe (N1: $p = 0.118$, N2: $p = 0.004$, CC41: $p = 0.100$, CC65: $p = 0.072$, and CC66: $p = 0.006$) and 10 of the Arawe to the TP Australians (Table 9). Three skulls in the TP group were incorrectly classified as belonging to the LH Australians and two as Tolai.

DFA of the size-adjusted data for the 174 cases and five groups produced four discriminant functions, with $\chi^2 = 621.9.0$, $p = 0.000$ (70.4% variance). There was still a strong association between

Table 7
Pooled within-group correlations between discriminating variables and standardized canonical discriminant functions for the first two functions in the unadjusted and size-adjusted DFAs. Variables ordered by absolute size of correlation within function.

Unadjusted	Function		Size-adjusted	Function	
	1	2		1	2
Parietal subt. h.	0.687*	0.006	Biparietal br.	0.371*	0.197
Occipital subt. h.	−0.611*	0.186	Frontal chord	0.119	0.713*
Frontal subt. h.	−0.288	0.508*	Frontal subt. h.	0.054	−0.591*
Frontal chord	0.195	−0.472	Parietal subt. h.	−0.381	0.548*
Parietal chord	0.146	0.233	Occiptal subt. h.	0.420	−0.495*
Biparietal br.	−0.338	−0.180	Occipital chord	−0.071	0.399*
Basion-bregma	0.264	0.078	Parietal chord	−0.087	0.112
Occipital chord	0.311	−0.071	Basion-bregma	−0.063	0.326

* largest absolute correlation between each variable and any discriminant function.

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

Table 8
Group classification results for discriminant function analysis of the *H. sapiens* and *H. erectus* crania completed on unadjusted/size-adjusted data for the highest group[a,b].

	TP	LH	Tolai	Arawe	*H. erectus*	Total	%Correct
TP	12/4	3/4	2/6	0/3	0/0	17	65/24
LH	3/2	23/22	8/9	0/1	0/0	34	62/65
Tolai	1/1	4/5	60/59	0/0	0/0	65	88/91
Arawe	1/2	3/1	4/8	44/41	0/0	52	81/79
H. erectus	0/0	0/0	0/0	0/0	5/5	5	100/100

[a] Group classification based on cross-validation in which each case is classified by the functions derived from all cases excluding that case.
[b] The probability of group membership is based on unequal sample sizes.

groups and predictors after the removal of the first function, with $\chi^2 = 279.5$, $p = 0.000$ (23.8% variance), and the third and fourth functions were also significant, although accounting for relatively little variance (Function 3: $\chi^2 = 80.4$, 4.6%, $p = 0.000$; Function 4: $\chi^2 = 19.1$, 1.3%, $p = 0.002$). The loading matrix of correlations between predictors and discriminant functions indicated that for the first function the best predictors are biparietal breadth, parietal subtense height, and occipital subtense height (Table 7). For the second function, the strongest predictors are frontal chord length and subtense height, parietal subtense height, and the length and curvature of the occipital bone. DFA of the size-adjusted data highlighted the shape differences between *H. erectus* and the *H. sapiens* samples, with intergroup centroid Mahalanobis D^2 distances between these two species considerably larger than with the raw data DFA (Table 10, Fig. 10). Group classification results for the size-adjusted data misclassified three of the TP Australians (N1: $p = 0.061$, CC41: $p = 0.581$, CC65: $p = 0.004$) as Arawe, with a small number of Arawe also misclassified to the other *H. sapiens* samples. Classification results for the second most probable group allocated 30 (58%) of the Arawe to the TP Australians, and two of the TP Australians to the Arawe (N2: $p = 0.164$, CC66: $p = 0.055$) (Tables 8 and 9).

In the size-adjusted DFA, group classification accuracy, based on cross-validation, was greatly reduced for TP Australians compared with the unadjusted data (raw: 65%, and adjusted: 24%), For all of the other groups the raw and size-adjusted DFAs maintained similar levels of misclassification. This highlights the impact of size (isometric scaling) on the morphological distinction between terminal Pleistocene and more recent Australian crania, and the presence of a small number of artificially modified crania within the TP Australian sample. These results are entirely consistent with previous analyses of the evidence for cranial modification in the Coobool Creek and Kow Swamp crania (Antón and Weinstein, 1999; Brown, 1981a, 1989; Durband, 2008a,b; Clark et al., 2007). None of the *H. erectus* crania was misclassified in either the raw or size-adjusted analyses. Mahalanobis D^2 distances emphasize the morphological differences between these Indonesian hominin crania and the modified and unmodified *H. sapiens* samples used in the DFAs. While *H. erectus* and the unmodified *H. sapiens* form distinct morphological units, the Arawe and TP Australians are more morphologically variable. With size-adjusted data the TP sample is split into two groups, primarily on the basis of biparietal breadth and parietal and occipital curvature (Function 1), and frontal chord and curvature (Function 2). In both the raw and size-adjusted DFAs, Nacurrie plots outside the unmodified *H. sapiens* and *H. erectus* distributions, and in the size-adjusted analysis it is misclassified as an Arawe.

Table 9
Group classification results for discriminant function analysis of the *H. sapiens* and *H. erectus* crania completed on unadjusted/size-adjusted data for the second highest group[a,b].

	TP	LH	Tolai	Arawe	*H. erectus*	Total	%Correct
TP	2/4	7/6	3/5	5/2	0/0	17	12/24
LH	2/12	11/11	20/11	1/0	0/0	34	32/32
Tolai	2/8	58/50	4/6	1/1	0/0	65	6/9
Arawe	10/30	16/7	25/13	1/2	0/0	52	1/4
H. erectus	1/0	4/5	0/0	0/0	0/0	5	0/0

[a] Group classification based on cross-validation in which each case is classified by the functions derived from all cases excluding that case.
[b] The probability of group membership is based on unequal sample sizes.

Table 10
Intergroup centroid Mahalanobis D^2 distances on raw and size-adjusted data for the *H. sapiens* and *H. erectus* samples.

	TP	LH	Tolai	Arawe	*H. erectus*
TP	0.00				
LH	13.7/9.1	0.00			
Tolai	17.3/9.9	9.7/10.8	0.00		
Arawe	23.8/29.5	24.0/34.7	23.4/34.7	0.00	
H. erectus	65.8/186.8	64.4/168.5	76.1/207.6	92.0/226.6	0.00

Principal Components Analysis of the raw data set extracted three components with eigenvalues >1.0. Principal Component I (35.8% of variance) gives the highest positive scores to crania that have high parietal curvature (large parietal subtense), long occipital chord, great cranial height (basion-bregma), and minimal occipital curvature (large occipital subtense) (Table 11). This separates most of the Arawe from the Tolai, and several of the TP Australians from the LH Australian series. Nacurrie and Coobool Creek 65 are outside the LH Australian range of variation, and within the Arawe distribution (Fig. 12). Both the Arawe and TP Australians show much greater morphological variation (dispersion) on Factor 1 than the Tolai and LH Australians. Principal Component II (21.0% of variance) gives the highest positive scores to crania with great biparietal breadth, in combination with low cranial height (basion-bregma) and minimal frontal curvature (long frontal subtense). This clearly separates the *H. erectus* sample from all of the *H. sapiens* samples.

The PCA of the size-adjusted data set extracted two components with eigenvalues >1.0. Principal Component I (eigenvalue 3.48; 43.5% of variance) gives the largest positive scores to crania that have minimal frontal curvature (large frontal subtense) in combination with great cranial height (basion-bregma), minimal occipital curvature (large occipital subtense), high parietal curvature (short parietal subtense), and elongated frontal and occipital chords (Table 11). This separates most of the Arawe from the Tolai, and several of the TP Australians from the LH Australian series. Nacurrie 1 and CC65 are outside the late Holocene Australian range of variation, and within the Arawe distribution (Fig. 12). Both the Arawe and TP Australians show much greater morphological variation (dispersion) on Factor 1 than do the Tolai and LH Australians. Principal Component II (eigenvalue = 1.90, 23.7% of variance) gives the highest positive scores to crania with great biparietal breadth, in combination with great occipital curvature (very short occipital subtense) and long frontal and parietal chords. This clearly separates the *H. erectus* sample from all of the modified and unmodified *H. sapiens*.

Plots of the factor scores and confidence ellipses for the raw and size-adjusted PCAs indicate the similarity in shape between the Tolai and LH Australians (Fig. 12). Their frontal, parietal, and occipital bones have very similar curvature in the sagittal plane, and their cranial dimensions have a comparable pattern of covariation. The TP Australian crania have significantly larger mean cranial dimensions than all of the other *H. sapiens* samples and this helps to separate them from late Holocene Australians in the raw PCA. It also divides them from the Arawe in the Factor 2 scores of the raw PCA. In the size-adjusted PCA, the similarity in shape between the Tolai and LH Australians is maintained and the distributions of the Arawe and TP Australians overlap. The PCA

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

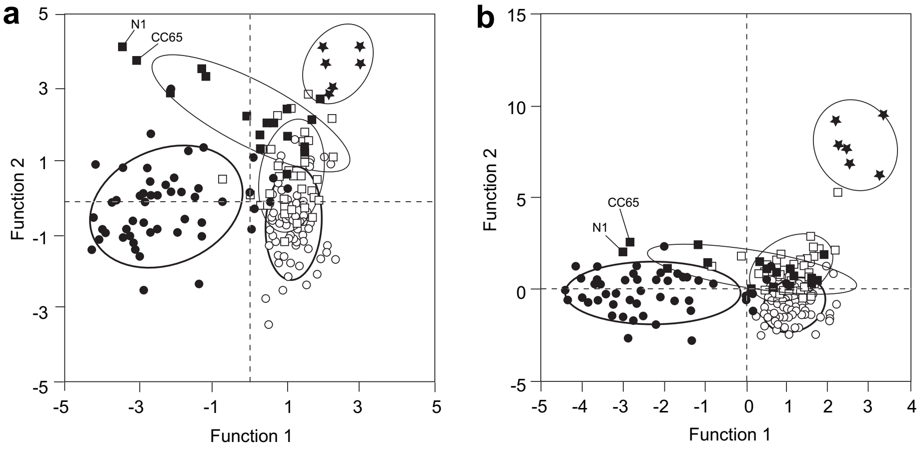

Figure 11. Bivariate plots of the first two function scores in the (a) unadjusted and (b) size-adjusted DFA analyses, with the sample distributions represented by sample confidence ellipses ($p > 0.68$): Tolai (circles), Arawe (black circles), LH (squares), TP (black squares), and Indonesian *H. erectus* (stars). The Tolai and Arawe ellipses have a thicker line. Individual specimens: Nacurrie (N1) and Coobool Creek 65 (CC65).

results indicate that while some of the early Australians have patterns of cranial covariation consistent with intentional deformation, some do not. This is consistent with previous statistical and morphological comparisons of these crania (Antón and Weinstein, 1999; Brown, 1981a, 1989; Durband, 2008a,b; Clark et al., 2007). In both the raw and size-adjusted PCAs, Nacurrie plots outside the unmodified *H. sapiens* and *H. erectus* distributions, and in the size-adjusted analysis it is close to the Arawe mean.

Discussion

In the size and shape of their neurocrania, and the morphology of their frontal, parietal, and occipital bones, the intentionally modified Arawe are distinct from their island neighbors, the Tolai. Although the Arawe have greater morphological and metric variation than is usual for unmodified *H. sapiens*, and overlap with the unmodified human range of variation to some degree, they also have a set of interrelated developmental traits that, in combination, are unique to modified crania. These traits include a frontal angle <20°, a depressed mid-frontal squama, constricted diploë in the mid-frontal, expanded diploë and a pre-bregmatic eminence in the posterior third of the frontal, a parietal saddle that is continuous across the sagittal suture, and an occipital angle <25°.

Importantly, these distinctive features are also present in some terminal Pleistocene Australian crania, including Nacurrie 1, KS5, and CC65, but not in Late Holocene and recent Australians. Multivariate comparison of size-adjusted data emphasized the relatively great cranial height, reduced frontal and parietal curvature, and increased parietal curvature in the Arawe compared to the Tolai.

Table 11
Variable loadings for the components in the unadjusted and size-adjusted PCA for the eight cranial dimensions.

Dimension	Raw data PCA			Size-adjusted PCA	
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2
Biparietal br.	−0.316	0.706	0.251	0.075	0.770
Basion-bregma	0.678	0.514	0.021	0.800	0.254
Frontal chord	0.546	0.423	0.381	0.645	0.476
Frontal subt. h.	−0.509	0.521	−0.416	−0.828	−0.126
Parietal chord	0.321	0.476	−0.726	0.336	−0.564
Parietal subt. h.	0.839	−0.163	−0.377	0.741	−0.571
Occipital chord	0.627	0.275	0.421	0.716	0.389
Occipital subt. h.	−0.745	0.376	0.095	−0.747	0.454

Size adjustment using Mosimann's shape ratios emphasizes allometric shape differences that may have been associated with cranial deformation, and helps remove the confounding effects of significant body mass differences between the TP and LH Australians. In the multivariate comparison, size adjustment reduced the Mahalanobis D^2 distances between the TP, LH, and Tolai group centroids, but greatly increased the distance between the modified Arawe and the other *H. sapiens*. Size adjustment emphasizes the distinctive shape of the Arawe crania, a shape shared by three of the TP Australians in the primary group classification results (NI, CC41, CC65). Even though preservation restricted variable selection and the size of the TP sample, excluding crania like KS1 (Thorne and Macumber, 1972), LM3 (Bowler and Thorne, 1976), and WLH50 (Stringer, 1998), the size-adjusted multivariate comparisons do not support morphological distinctions between terminal Pleistocene and recent indigenous Australians, except where cranial deformation is present. While the Indonesian *H. erectus* sample was distinct from the unmodified and modified *H. sapiens* in both morphological and statistical comparisons, size adjustment greatly increased the Mahalanobis D^2 distances between the *H. erectus* and *H. sapiens* group centroids, emphasizing the distinctive cranial morphology of the former.

In both shape and characteristics of their frontal, parietal, and occipital morphology, Indonesian *H. erectus* skulls are distinct from terminal Pleistocene and more recent Australians. The Indonesians share a low frontal angle with the Arawe and some of the terminal Pleistocene Australians; however, *H. erectus* combines this with a relatively low cranial height, minimal curvature of the parietals in the sagittal plane, and sharply angled superior and inferior occipital scales. None of the Australian crania has a supraorbital torus of the form common in the Indonesian hominins, with maximum thickness laterally at the zygomatic trigone (Santa Luca, 1980). A small number of terminal Pleistocene, and more recent Australian crania, have a true supraorbital torus (Cunningham, 1908; Brown, 1989). However, all of these have tori that are dominated by prominent, distinct, superciliary ridges with maximum supraorbital thickness located medially. It is not uncommon for late Holocene male Australian Aboriginal crania to have a metopic ridge, as in *H. erectus*, but this feature is either poorly developed, or absent, in terminal Pleistocene crania with extremely low frontal angles, mid-frontal lateral depressions, and constricted mid-frontal diploë. While Australian Aboriginal crania, particularly the large-bodied terminal Pleistocene crania, have relatively thickened cranial vault bone, the thickened lateral walls and reinforced cranial base of *H. erectus* are not present (Weidenreich, 1943; Brown, 1987a, 1994b). None of the Indonesian *H. erectus* crania has the

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

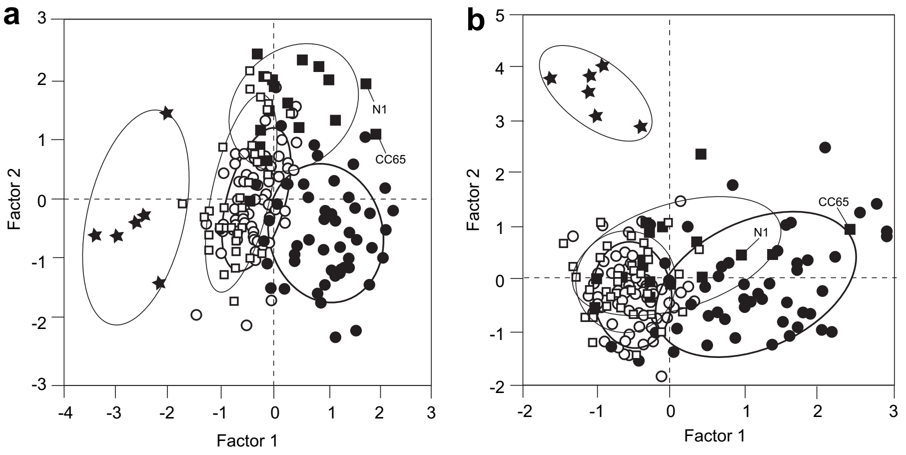

Figure 12. Bivariate plots of the first two component scores in the (a) unadjusted and (b) size-adjusted PCA analyses, with the distributions represented by sample confidence ellipses ($p > 0.68$), Tolai (open circles) and Arawe (black circles), LH (open squares), TP (black squares) and Indonesian *H. erectus* (stars), with the Tolai and Arawe ellipses having a thicker line. Individual specimens: Nacurrie (N1), Coobool Creek 65 (CC65).

sagittal vault thickness profile of constricted mid-frontal diploë, greatly expanded diploë in a pre-bregmatic eminence, and parietal saddle, seen in some of the terminal Pleistocene Australians (Brown, 1994b; Baba et al., 2003).

Most of the morphological differences between Indonesian *H. erectus* and *H. sapiens* examined here just emphasize the differences in grade between these two species. This distinction becomes more apparent as a result of the effects of cranial deformation on the terminal Pleistocene crania from Kow Swamp, Coobool Creek, and Nacurrie. While certain crania, like KS5, have a flattened and elongated frontal bone, the details of their cranial morphology are consistent with the effects of cranial deformation (Brown, 1981a; Antón and Weinstein, 1999; Clark et al., 2007; Durband, 2008a) and not evidence of a separate "robust" founder population (Thorne, 1976, 1977; Curnoe and Thorne, 2006; Curnoe, 2007). Similarly, this does not seem to reflect morphology descendant from Javan *H. erectus* (Thorne and Macumber, 1972; Thorne, 1981; Thorne and Wolpoff, 1981). The latter has always seemed particularly improbable given several factors, including morphological distinctions between *H. erectus* and modern *H. sapiens*, (Weidenreich, 1951; Rightmire, 1990; Antón, 2003; Baba et al., 2003), modern human skeletal anatomy at Lake Mungo ≥26 ka (Bowler et al., 1970, 1972; Bowler and Thorne, 1976; Brown, 1987b, 2000), and the presence of anatomically modern humans in Australia by 40–45 ka (O'Connell and Allen, 2004). In contrast, *H. erectus* may have persisted on Java until as recently as 27–53 ka (Swisher et al., 1996; Yokoyama et al., 2008). The increasing evidence for gradual evolutionary changes within Javan *H. erectus,* and the presence of autapomorphies, also makes it increasingly improbable that this species contributed to the local *H. sapiens* gene pool (Kaifu et al., 2008).

Cranial deformation in the Arawe resulted from a newborn infant's head being wrapped with bandages and twine shortly after birth (Blackwood and Danby, 1955) (Fig. 3). As a neonate's neurocranium is malleable, with thin vault bone, large anterior, posterior, and posterolateral fontanelles, and a frontal bone that is separated into two halves by the metopic suture, firmly wrapping the skull easily moulds it to a different shape (Moloy, 1942): an extension of the normal moulding that may take place as the infant's head passes through the birth canal (Graham and Smith, 2007). At the same time, as bandages are restricting the growth of the vault ectocranially, a rapidly growing brain maintains pressure on the meninges and endocranial surface of the neurocranium. As the usual expansions in the frontal and occipital regions of the brain and neurocranium are prevented, there is a compensatory expansion and distortion of the parietals, and a redirection of growth in the frontal and occipital bones. If pressure on the growing vault is maintained until the fontanelles have fused and the vault bone thickened, the modified vault shape is maintained throughout life (Özbek, 2001). This is similar to positional plagiocephaly in infants, where sleeping on their back with the head resting on a firm surface can result in asymmetrical distortion with flattening of the back of the head (Neufeld and Birkett, 2000; Graham and Smith, 2007). Positional plagiocephaly can be corrected with cranial remodeling orthoses that work in a comparable manner to the Arawe's head bindings. Growth is inhibited in one direction and promoted in another, permanently changing a skull's shape. If they are applied between 6 and 9 months of age, when the brain is growing rapidly, remodeling appliances can permanently adjust head shape through preferential pressure on parts of the cranial vault within 3–5 months (Teichgraeber et al., 2002, 2004; Graham and Smith, 2007).

In a study of circumferential cranial modification in a Chalcolithic subadult sample from Degirmentepe, Turkey, Özbek (2001) noted changes in cranial contours, and the morphology of the frontal and parietal bones, which gives some insight into the development of these traits in adult Arawe. In infants with a dental developmental age of 4–5 months and an open anterior fontanelle, the frontal bone is flattened in its posterior half, the parietals bend and protrude supero-posteriorly, and maximum cranial height (vertex) is located posteriorly. The inferior half of the occipital bone is flattened and the antero-posterior length of the cranial vault increased. In older infants (dental age 6–7 months), the frontal boss is less pronounced, the mid-frontal squama is concave, flattening has extended to the superior half of the occipital, and the length of the neurocranium further increased. By 18 months of age, a prominent pre-bregmatic eminence and distinctive parietal saddle are present. Özbek (2001) speculated that separate bandages were responsible for the depressed parietal posterior to the coronal suture and the convex mid-frontal squama. As both of these traits are present in adult Arawe, where separate circumferential bandages were not applied when they were infants (Fig. 3), this explanation seems unlikely. There would also be little point in trying to produce a parietal saddle as they are relatively subtle features and this part of the skull is usually covered by hair. Parietal saddles are more likely the result of the disruption of normal growth through circumferential bandaging, its effect on osteogenesis in the anterior fontanelle, and osteogenic membranes at the sutures (Cohen, 2000), combined with pressure exerted by the

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

expanding meninges. External pressure forces the frontal backwards, the occipital towards the frontal, and bends the parietals. The diploë in the posterior frontal expands, the external table of the frontal is pushed supero-posteriorly towards the coronal suture, while the parietals are pushed anteriorly. In a band running coronally, adjacent to the coronal suture, the ectocranial and endocranial surfaces of the parietals are distorted and bent inwards. There is a compensatory physiologic response, with bony outgrowth at the osteogenic membrane (Moloy, 1942). In the Arawe, this is most evident in crania with greater antero-posterior curvature of the parietals (Fig. 5).

As has been demonstrated previously (Brothwell, 1975; Brown, 1981a, 1989; Antón and Weinstein, 1999; Durband, 2008a,b), a number of terminal Pleistocene crania from south-eastern Australia have morphological and metric features consistent with being artificially modified. This is most evident in the frontal bone, which may be elongated, have a depressed mid-frontal squama, constricted mid-frontal diploë, and pre-bregmatic eminence, but is also reflected in the shape of the parietal and occipital bones, and cranial height and breadth relationships. Currently, evidence of intentional deformation is restricted to three terminal Pleistocene–early Holocene sites, Coobool Creek, Nacurrie, and Kow Swamp, separated on a transect running south-east to north-west by approximately 100 km, and all close to the Murray River. The mid-Holocene cemetery at Barham (from 5400 ± 90 ka to 4670 ± 110 ka) (Daley, 1986), 20 km from Nacurrie, does not have any evidence of cranial deformation, or the large skeletal and dental dimensions evident in the terminal Pleistocene sites (Brown, 1989). The same is true of the Wenworth cemetery, 5900 ± 550 ka, 200 km to the west of Coobool Creek, and also located adjacent to the Murray River (Blackwood and Simpson, 1973; Brown, 1989, 1992b). Although there is an ethnographic account of cranial deformation from northern Victoria in 1841 (Kenyon, 1928), there was no evidence of this practice in the several thousand crania from the Murray River region that, prior to repatriation in the 1980s, formed parts of museum collections in Melbourne, Adelaide, and Canberra (Brown, 1989). There are more detailed, and probably more reliable, descriptions of infant head pressing from Cape York, northern Australia (Brierly, 1848–1850; Macgillivray, 1852). “Pressure is made by the mother with her hands…one being applied to the forehead and the other to the occiput, both of which are thereby flattened, while the skull is rendered proportionally broader and longer than it would naturally have been” (Macgillivray, 1852: 12). However, corroborating skeletal evidence of this behaviour is not present in the limited skeletal evidence in museum collections from northern Australia, or the published literature on cranial morphological variation in the north-eastern part of the continent (Larnach and Macintosh, 1970).

Although morphological and metric variation in some of the terminal Pleistocene Australians falls within the Arawe range of variation, they are most similar in the sagittal contours, angles, and anatomy of the frontal bone, and less so in the posterior neurocranium. This is most evident in the extent of parietal curvature, depth of the parietal saddle, and flattening of the occipitals at Kow Swamp, Coobool Creek, and Nacurrie. If the Australians had had their heads modified as infants by circumferential bandages or cradle boards, this would have produced more substantial modification in the posterior part of the skull (Dingwall, 1931; Kiszelly, 1989; Özbek, 2001; Torres-Rouff, 2002; Schijman, 2005; Perez, 2007). While several of the TP Australians have FCI values matching the Arawe extreme, there is no evidence of the same degree of compensatory increase in the PCI present in the Arawe, with significant differences in their OLS slopes (Table 6, Fig. 10). This is not what would be predicted from the use of fixed appliances, bandages, caps, or boards, to modify head shape. As these procedures must be applied while the infant’s cranium is malleable, but undergoing rapid growth, any prolonged constriction on growth of the frontal and occipital regions will result in compensatory expansion of the parietals to accommodate the expanding brain and meninges. It is also unlikely that the distinctive head shape of some TP Australians was simply the result of the use of fixed appliances being used over shorter time periods. This would not be consistent with the degree of frontal modification, which suggests pressure was applied to the frontal bone until osteogenesis at the anterior fontanelle was complete.

The more subtle distortion of head shape may be the result of repetitive hand manipulation by the neonate’s mother, similar to the procedure reported by Macgillivray (1852) for Cape York, and a practice still used for aesthetic reasons by some mothers today (Adebonojo, 1991; Dobson, 1994; Fitzsimmons et al., 1998). Fitzsimmons et al.’s (1998) survey of an ethnically diverse group of mothers, found that head shape was changed by rubbing in a circular motion around the entire head, upward pressure from the brow ridges over the fontanelle with one hand, while the other hand applies pressure to the occiput, or manual pressure applied simultaneously to each side of the skull. Selective application of pressure depended upon the desired final head shape. Mothers repeated the hand shaping at least once a day, for up to a year, or until the anterior fontanelle was fused. No adverse effects have been reported from infant head moulding and only gentle hand pressure is required to alter the shape of a neonate’s vault.

Where historical or ethnographic records exist, modern humans modified the shape of their children’s heads for reasons ranging from community expectations over the most aesthetic appearance, to beliefs about the association between head shape and intelligence, or a desire to distinguish one group of people from another (Dingwall, 1931; Adebonojo, 1991; Dobson, 1994; Fitzsimmons et al., 1998). Most recently, the shape of an infant’s head has accidentally been modified, with asymmetrical posterior flattening as a result of positioning neonates on their back while sleeping in order to reduce the possibility of sudden infant death syndrome (SIDS). The flattening of the skull that may result (Argenta et al., 1996) is often not considered aesthetic, and remedial head moulding may follow. In this instance, the positional plagiocephaly provides direct information on preferential sleeping behaviours of the infant, or the infant’s mother. It would be unusual, I expect, to find similar posterior flattening in a wild arboreal primate, or any primate that did not sleep, as an infant, in a supine position with their head on a firm surface. A certain level of social security and freedom from predation would be required to sleep in this position (Anderson, 1998; Fruth and McGrew, 1998; DiBitetti et al., 2000). Unfortunately, interpretation of the cultural significance of cranial deformation in the terminal Pleistocene of the central Murray River region is more problematic. The available evidence indicates that this behaviour was restricted both in time and geography. Given the geographic proximity of Kow Swamp, Coobool Creek, and Nacurrie, and the similarities in skeletal morphology, skeletal robusticity, and body mass (Brown, 1987b, 1989, 1992b), it seems likely that they were a closely related group of people. Both male and female crania show evidence of deformation, and there is considerable variation, from clearly deformed to those that are difficult to classify (Brown, 1981b; Antón and Weinstein, 1999; Durband, 2008a,b). The variation might reflect the diligence and expertise of the mother, or changes in community attitudes to desirable head shape. As neonates are usually in their mother’s care, it seems most probable that head shaping was carried out by the mother, possibly with the support of female relatives, during the first six months postpartum. The reasons why head shapes were modified will remain a matter for speculation, as will the details of why this practice was adopted and then discontinued. While head shaping may have been practiced in northern Australia

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother’s hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

at the time of European contact, there is absolutely no evidence of continuity of this behaviour through the Holocene.

Conclusion

The Nacurrie 1 cranium, and crania from the temporally and geographically proximate sites of Kow Swamp and Coobool Creek, south-eastern Australia, show evidence of artificial modification or deformation. Existing skeletal evidence indicates that this cultural practice was used during the terminal Pleistocene and early Holocene, but was then discontinued. The most probable method of deforming a neonate's neurocranium was with repetitive hand moulding, by the infant's mother during the first six months of life. Nacurrie 1, and the other late Pleistocene crania from Australia, including KS5, do not display evidence of evolutionary continuity with Javan *H. erectus*, at least in the shape and morphology of their frontal bones. Apart from cranial modification, the most distinctive feature of terminal Pleistocene–early Holocene Australians, compared with late Holocene populations from the same geographic region, was the significantly greater average body mass, skeletal robusticity, and tooth size in the terminal Pleistocene. Size adjustment highlights similarities in vault shape between terminal Pleistocene and recent crania from the same geographic region, more clearly identifies modified crania within the terminal Pleistocene Australian sample and increases the morphological distance between *H. sapiens* and *H. erectus*.

Acknowledgements

For access to skeletal collections I am grateful to Chris Stringer and Rob Kruszynski, of the Natural History Museum, London; the Late Professor L. Ray and Professor G. Ryan, Department of Anatomy, University of Melbourne; Department of Anthropology, Australian Museum, Sydney; Department of Anatomy, Sydney University; Department of Anthropology, Queensland Museum, Brisbane; the late Graeme Pretty, South Australian Museum, Adelaide; Tasman Brown, Grant Townsend, and Lindsay Richards, Dentistry, Adelaide University; Department of Anthropology, Museum of Victoria; Alan Thorne, Australian National University; Yuji Mizuguchi, Hisao Baba, and Yoseke Kaifu, National Science Museum, Tokyo; Jens Franzen, Naturmuseum Senckenberg, Frankfurt; John Devos, Naturalis, Leiden; and Fachroel Aziz, GRDC, Bandung. Mrs. A. Macintosh kindly provided copies of correspondence documenting the late Professor N.W.G. Macintosh's work with the Nacurrie skeleton. Perceptive comments by Steven Leigh and five anonymous reviewers improved an earlier draft of this manuscript, as did subediting by Steven Leigh and Natalie Uhl. In the years 1980–2009, financial support for the collection of data for this project were provided by the Australian National University, Australian Research Council, Tohoku University Medical School, and the University of New England.

References

Ackermann, R.R., 2002. Patterns of covariation in the hominoid craniofacial skeleton: implications for paleoanthropological models. J. Hum. Evol. 43, 167–187.

Ackermann, R.R., 2005. Ontogenetic integration of the hominoid face. J. Hum. Evol. 48, 175–197.

Adcock, G.J., Dennis, E.S., Easteal, S., Huttley, G.A., Jermlin, L.S., Peacock, W.J., Thorne, A., 2001. Mitchondrial DNA sequences in ancient Australians: implications for modern human origins. Proc. Natl. Acad. Sci. 98, 537–542.

Adebonojo, F.O., 1991. Infant head shaping. J. Am. Med. Assoc. 265, 1179.

Anderson, J.R., 1998. Sleep, sleeping sites, and sleep-related activities: awakening to their significance. Am. J. Primatol. 46, 63–75.

Antón, S.C., 1989. Intentional cranial vault deformation and induced changes of the cranial base and face. Am. J. Phys. Anthropol. 79, 253–267.

Antón, S.C., 2003. Natural history of *Homo erectus*. Yearb. Phys. Anthropol. 46, 126–169.

Antón, S.C., Weinstein, K.J., 1999. Artificial cranial deformation and fossil Australians revisited. J. Hum. Evol. 36, 195–209.

Argenta, L.C., David, L.R., Wilson, J.A., Bell, W.O., 1996. An increase in infant cranial deformity with supine sleeping position. J. Craniofac. Surg. 7, 5–11.

Aziz, F., Baba, H., Watanabe, N., 1996. Morphological study on the Javanese *Homo erectus* Sangiran 17 skull based upon a new reconstruction. Geol. Res. Devel. Cent. Paleontol. Ser. 8, 11–25.

Baba, H., Aziz, F., Kaifu, Y., Suwa, G., Kono, R.T., Jacob, T., 2003. *Homo erectus* calvarium from the Pleistocene of Java. Science 299, 1384–1388.

Barker, G., Barton, H., Bird, M., Daly, P., Datan, I., Dykes, A., Farr, L., Gilbertson, D., Harrisson, B., Hunt, C., Higham, T., Kealhofer, L., Krigbaum, J., Lewis, H., McLaren, S., Paz, V., Pike, A., Piper, P., Pyatt, B., Rabett, R., Reynolds, T., Rose, J., Rushworth, G., Stephens, M., Stringer, C., Thompson, J., Turney, C., 2007. The 'human revolution' in lowland tropical Southeast Asia: the antiquity and behavior of anatomically modern humans at Niah Cave (Sarawak, Borneo). J. Hum. Evol. 52, 243–261.

Barrett, M.J., 1977. Masticatory and non-masticatory uses of teeth. In: Wright, R.S.V. (Ed.), Stone Tools as Cultural Markers: Change, Evolution and Complexity. Australian Institute of Aboriginal Studies, Canberra, pp. 18–23.

Benus, R., Masnicova, S., Lietava, J., 1999. Intentional cranial vault deformation in a Slavonic population from the medieval cemetery in Devin (Slovakia). Int. J. Osteoarchaeol. 9, 267–270.

Birdsell, J.B., 1967. Preliminary data on the trihybrid origin of the Australian Aborigines. Archaeol. Phys. Anthropol. Oceania 2, 100–155.

Birdsell, J.B., 1977. The recalibration of a paradigm for the first peopling of greater Australia. In: Allen, J., Golson, J., Jones, R. (Eds.), Sunda and Sahul. Prehistoric Studies in Southeast Asia, Melanesia and Australia. Academic Press, London, pp. 113–167.

Birdsell, J.B., 1993. Microevolutionary Patterns in Aboriginal Australia: a Gradient Analysis of Clines. Oxford University Press, New York.

Blackwood, B., Danby, P.M., 1955. A study of artificial cranial deformation in New Britain. R. Anthropol. Inst. J. 85, 173–191.

Blackwood, R., Simpson, K.N.G., 1973. Attitudes of Aboriginal skeletons excavated in the Murray Valley region between Mildura and Renmark, Australia. Mem. Nat. Mus. Victoria 34, 99–150.

Bonin, G.V., 1936. On the craniology of Oceania. Crania from New Britain. Biometrika 28, 123–148.

Bowler, J.M., Jones, R., Allen, H., Thorne, A.G., 1970. Pleistocene human remains from Australia: a living site and human cremation from Lake Mungo, western New South Wales. World Archaeol. 2, 39–60.

Bowler, J.M., Thorne, A.G., Polach, H., 1972. Pleistocene man in Australia: age and significance of the Mungo skeleton. Nature 240, 48–50.

Bowler, J.M., Magee, J., 2000. Redating Australia's oldest human remains: a sceptics' view. J. Hum. Evol. 38, 719–726.

Bowler, J.M., Thorne, A.G., 1976. Human remains from Lake Mungo: discovery and excavation of Lake Mungo III. In: Kirk, R.L., Thorne, A.G. (Eds.), The Origin of the Australians. Australian Institute of Aboriginal Studies, Canberra, pp. 127–138.

Brace, O.L., Shae, X.-Q., Zhang, Z.-B., 1984. Prehistoric and modern tooth size in China. In: Smith, F.H., Spencer, F. (Eds.), The Origins of Modern Humans. Alan R. Liss, New York, pp. 485–516.

Bräuer, G., 1989. The evolution of modern humans: a comparison of the African and non-African evidence. In: Mellars, P., Stringer, C.B. (Eds.), The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans. University of Edinburgh Press, Edinburgh, pp. 123–143.

Brierly, D.W., 1848–1850. Journals and Manuscripts. Mitchell Library, Sydney.

Brothwell, D.R., 1960. Upper Pleistocene human skull from Niah Caves. Sarawak Mus. J. 9, 323–349.

Brothwell, D., 1975. Possible evidence of a cultural practise affecting head growth in some late Pleistocene East Asian and Australasian populations. J. Archaeol. Sci. 2, 75–77.

Brown, P., 1981a. Artificial cranial deformation: a component in the variation in Pleistocene Australian Aboriginal crania. Archaeol. Oceania 16, 156–167.

Brown, P., 1981b. Sex determination of Australian Aboriginal crania from the Murray River Valley: a reassessment of the Larnach and Freedman technique. Archaeol. Oceania 16, 53–63.

Brown, P., 1987a. Cranial vault thickness in Northern Chinese, European and Australian Aboriginal populations. Acta Anthropol. Sinica. 6, 10–15.

Brown, P., 1987b. Pleistocene homogeneity and Holocene size reduction: the Australian human skeletal evidence. Archaeol. Oceania 22, 41–71.

Brown, P., 1989. Coobool Creek: a Morphological and Metrical Analysis of the Crania, Mandibles and Dentitions of a Prehistoric Australian Human Population. Department of Prehistory, Australian National University, Canberra.

Brown, P., 1992a. Post-Pleistocene change in Australian Aboriginal tooth size: dental reduction or relative expansion? In: Brown, T., Molnar, S. (Eds.), Human Craniofacial Variation in Pacific Populations. Anthropology and Genetics Laboratory, University of Adelaide, Adelaide, pp. 33–52.

Brown, P., 1992b. Recent human evolution in East Asia and Australasia. Phil. Trans. R. Soc. B 337, 235–242.

Brown, P., 1994a. Human skeletons. In: Horton, D. (Ed.), The Encyclopedia of Aboriginal Australia. Australian Aboriginal Studies Press, Canberra, pp. 990–991.

Brown, P., 1994b. Vault thickness in Asian *Homo erectus* and modern *Homo sapiens*. Cour. Forsch.-Inst. Senckenberg 171, 33–46.

Brown, P., 1997a. Australian Palaeoanthropology. In: Spencer, F. (Ed.), History of Physical Anthropology: An Encyclopedia. Garland Publishing, New York, pp. 138–145.

Brown, P., 1997b. WLH-50 Web page at: http://www.une.edu.au/Arch/PalaeoIndex.html.

Brown, P., 2000. Australian Pleistocene variation and the sex of Lake Mungo 3. J. Hum. Evol. 38, 743–750.

Brown, T., Pinkerton, S.K., Lambert, W., 1979. Thickness of the cranial vault in Australian Aboriginals. Arch. Phys. Anthropol. Oceania 14, 54–71.

Brown, P., Maeda, T., 2004. Post-Pleistocene diachronic change in East Asian facial skeletons: the size, shape and volume of the orbits. Anthropol. Sci. 112, 29–40.

Caddie, D.A., Hunter, D.S., Pomery, P.J., Hall, H.J., 1987. The ageing chemist – can electron spin resonance (ESR) help. In: Ambrose, W.R., Mummery, J.M. (Eds.), Archaeometry: Further Australasian Studies. Department of Prehistory, Australian National University, Canberra, pp. 167–176.

Calcagno, J.M., 1986. Dental reduction in post-Pleistocene Nubia. Am. J. Phys. Anthropol. 70, 349–363.

Campbell, T.D., 1925. Dentition and Palate of the Australian Aboriginal. Hassell Press, Adelaide.

Campbell, T.D., 1939. Food, food values and food habits of the Australian Aborigines in relation to their dental conditions. Aust. J. Dent. 43, 1–15, pp. 45–55, 73–87, 141–156, 178–198.

Chase, K., Carrier, D.R., Adler, F.A., Jarvik, T., Ostrander, E.A., Lorentzen, T.D., Lark, K. G., 2002. Genetic basis for systems of skeletal quantitative traits: principal component analysis of the canid skeleton. Proc. Natl. Acad. Sci. 99, 9930–9935.

Clark, J.L., Dobson, S.D., Antón, S.C., Hawks, J., Hunley, K.L., Wolpoff, M.H., 2007. Identifying artificially deformed crania. Int. J. Osteoarchaeol. 17, 596–607.

Cohen, M.M., 2000. Sutural biology. In: Cohen, M.M., MacLean, R.E. (Eds.), Craniosynostosis: Diagnosis, Evaluation, and Management, second ed. Oxford University Press, New York.

Cooper, A., Rambaut, A., Macaulay, V., Willerslev, E., Hansen, A.J., Stringer, C., 2001. Human origins and ancient DNA. Science 292, 1655–1656.

von Cramon-Taubadel, N., Ling, E.N., Cotter, D., Wilkins, N.P., 2005. Determination of body shape variation in Irish hatchery-reared and wild Atlantic salmon. J. Fish Biol. 66, 1471–1482.

Cunningham, D.J., 1908. The evolution of the eyebrow region of the forehead, with special reference to the excessive supraorbital development in the Neanderthal race. Trans. R. Soc. Edinburgh 46, 283–311.

Curnoe, D., 2007. Modern human origins in Australasia: testing the predictions of competing models. Homo 58, 117–157.

Curnoe, D., 2009. Possible causes and significance of cranial robusticity among Pleistocene–early Holocene Australians. J. Archaeol. Sci. 36, 980–990.

Curnoe, D., Thorne, A., 2006. Human origins in Australia: the skeletal evidence. Before Farming [on-line version] 2006/1 Article 5.

Cybulski, J.S., 1989. Skeletal Variability in British Columbia Coastal Populations: a Descriptive and Comparative Assessment of Cranial Morphology. National Museum of Canada, Ottawa.

Daley, C., 1986. The Barham Skeletons. MA Dissertation, University of Sydney.

Dampier, W., 1697. A New Voyage Round the World. James Knapton, London.

Darroch, J.N., Mosimann, J.E., 1985. Canonical and principle components of shape. Biometrika 72, 241–252.

David, B., Roberts, R., Tuniz, C., Jones, R., Head, J., 1997. New optical and radiocarbon dates from Ngarrabullgan Cave, a Pleistocene archaeological site in Australia: implications for the comparability of time clock and for the human colonization of Australia. Antiquity 71, 183–188.

Delson, E., Harvati, K., Reddy, D., Marcus, L.F., Mowbray, K., Sawyer, G.J., Jacob, T., Marquez, S., 2001. The Samungmacan 3 *Homo erectus* calvaria: a comparative morphometric and morphological analysis. Anat. Rec. 262, 380–397.

DiBitetti, M.S., Vidal, E.M.L., Baldovino, M.C., Benesovsky, V., 2000. Sleeping site preferences in tufted capuchin monkeys (Cebus paella nigritus). Am. J. Primatol. 50, 257–274.

Dingwall, E.J., 1931. Artificial Cranial Deformation: a Contribution to the Study of Ethnic Mutilations. John Bale, Sons and Danielsson, London.

Dobson, J., 1994. Baby Beautiful: a Handbook of Baby Head Shaping. Heirs Press, Carson City, NV.

Dubois, E., 1922. The proto-Australian fossil man of Wadjak, Java. Kon. Akad. Wetensch. Amsterdam B 23, 1013–1051.

Durband, A., 2008a. Artificial cranial deformation in Kow Swamp 1 and 5: a response to Curnoe (2007). Homo 59, 261–269.

Durband, A., 2008b. Artificial cranial deformation in Pleistocene Australians: the Coobool Creek sample. J. Hum. Evol. 54, 795–813.

Fifield, L.K., Bird, M.I., Turney, C.S.M., Hausladen, P.A., Santos, G.M., di Tada, M.L., 2001. Radiocarbon dating of the human occupation of Australia prior to 40 ka BP – successes and pitfalls. Radiocarbon 43, 1139–1145.

Fitzsimmons, E., Prost, J.H., Peniston, S., 1998. Infant head molding: a cultural practice. Arch. Fam. Med. 7, 88–90.

Freedman, L., 1986. Human skeletal remains from Mossgiel, New South Wales. Archaeol. Oceania 20, 21–31.

Freedman, L., Lofgren, M., 1983. Human skeletal remains from Lake Tandou, New South Wales. Archaeol. Oceania 18, 98–105.

Friess, M., Baylac, M., 2003. Exploring artificial cranial deformation using elliptic Fourier analysis of Procrustes aligned outlines. Am. J. Phys. Anthropol. 122, 11–22.

Fruth, B., McGrew, W.C., 1998. Resting and nesting in primates: behavioral ecology of inactivity. Am. J. Primatol. 46, 3–5.

Gillespie, R., Roberts, R.G., 2000. On the reliability of age estimates for human remains at Lake Mungo. J. Hum. Evol. 38, 727–732.

Gilligan, L., Bullbeck, D., 2007. Environment and morphology in Australian Aborigines: a re-analysis of the birdsell database. Am. J. Phys. Anthropol. 134, 75–91.

Goldstein, M.S., 1940. Cranial deformation among Texas Indians. Am. J. Phys. Anthropol. 27, 312–313.

Graham, J.M., Smith, D.W., 2007. Smith's Recognizable Patterns of Human Deformation. Elsevier Health Sciences, New York.

Groves, C.P., 1989. A regional approach to the problems of the origin of modern humans in Australasia. In: Mellars, P., Stringer, C. (Eds.), The Human Revolution. Behavioral and Biological Perspectives on the Origins of Modern Humans. Princeton University Press, Princeton, New Jersey, pp. 274–285.

Habgood, P.J., 1989. The origin of anatomically-modern humans in Australasia. In: Mellars, P., Stringer, S. (Eds.), The Human Revolution. Princeton University Press, Princeton, pp. 245–273.

Hanhirara, T., 1992. Negritos, Australian Aborigines, and the "Proto-Sundadont" dental pattern: the basic populations in East Asia. V. Am. J. Phys. Anthropol. 88, 183–196.

Hiscock, P., 2008. Archaeology of Ancient Australia. Routledge, London.

Howells, W.W., 1973. Cranial Variation in Man. Peabody Museum of Archaeology and Ethnology. Harvard University, Cambridge, Massachusetts.

Howells, W.W., 1976. Metrical analysis in the problem of Australian origins. In: Kirk, R.L., Thorne, A.G. (Eds.), The Origin of the Australians. Australian Institute of Aboriginal Studies, Canberra, pp. 141–160.

Howells, W.W., 1989. Skull Shapes and the Map. Craniometric Analyses in the Dispersion of Modern *Homo*. Peabody Museum of Archaeology and Ethnology, Havard University, Cambridge, Massachusetts.

Howells, W.W., 1995. Who's Who in Skulls. Peabody Museum of Archaeology and Ethnology, Cambridge.

Hudjashov, G., Kivisild, T., Underhill, P.A., Endicott, P., Sanchez, J.J., Lin, A.A., Shen, P., Oefner, P., Renfrew, C., Villems, R., Forster, P., 2007. Revealing the prehistoric settlement of Australia by Y chromosome and mtDNA analysis. Proc. Natl. Acad. Sci. 104, 8726–8730.

Huxley, T.H., 1870. On the geographical distribution of the chief modifications of mankind. Ethnol Soc. J. Lond. 2, 404–412.

Jackson, J.E., 1991. A User's Guide to Principal Components. Wiley, New York.

Jacob, T., 1976. Early populations in the Indonesian region. In: Kirk, R.L., Thorne, A.G. (Eds.), The Origin of the Australians. Australian Institute of Aboriginal Studies, Canberra, pp. 81–94.

Jungers, W.L., Falsetti, A.B., Wall, C.E., 1995. Shape, relative size, and size-adjustments in morphometrics. Yearb. Phys. Anthropol. 38, 137–161.

Kaifu, Y., Aziz, F., Indriati, E., Jacob, T., Kurniawan, I., Baba, H., 2008. Cranial morphology of Javanese *Homo erectus*: new evidence for continuous evolution, specialization, and terminal extinction. J. Hum. Evol. 55, 551–580.

Kennedy, K.A.R., 1977. The deep skull of Niah: an assessment of twenty years of speculation concerning its evolutionary significance. Asian Perspect. 20, 32–50.

Kenyon, A.S., 1928. The Aboriginal Protectorate of Port Phillip. Report of an expedition to the Aboriginal tribes of the western interior by the Chief Protector, George Augustus Robinson. Vict. Hist. Mag. 12, 134–171.

Kiszelly, I., 1989. The Origins of Artificial Cranial Formation in Eurasia. In: BAR International Series (Supplementary), vol. 50 London.

Klaatsch, H., 1908. The skull of the Australian Aboriginal. Rep. Path. Lab. Lunacy Dept., New South Wales 1, 43–167.

Knuckey, G., 1992. Patterns of fracture upon Aboriginal crania from the recent past. In: Bruce, N.W. (Ed.), Living with Civilisation. Centre for Human Biology, University of Western Australia, Perth, pp. 47–58.

von Koenigswald, W., 1940. Neue Pithecanthropus funde 1936–1938. Ein Beitrag zur Kenntnis der Praehominiden. Wet. Meded. K. Ned. Natuurhist. 28, 1–232.

Krogman, W.M., 1955. The skeleton in forensic medicine. Postgrad. Med. J. 17, A48–A62.

Kroon, D.F., Lawson, M.L., Derkay, C.S., Hoffman, K., McCook, J., 2002. Surfer's ear: external auditory exostoses are more prevalent in cold water surfers. Otolaryngol. Head Neck Surg. 126, 499–504.

Lahr, M.M., 1994. The multiregional model of modern human origins: a reassessment of its morphological basis. J. Hum. Evol. 26, 23–56.

Lahr, M.M., Wright, R.V.S., 1996. The question of robusticity and the relationship between cranial size and shape in *Homo sapiens*. J. Hum. Evol. 31, 157–191.

Larnach, S.L., 1974. Frontal recession and artificial deformation. Arch. Phys. Anthropol. Oceania 3, 214–216.

Larnach, S.L., 1976. The parietal boss (or eminence): estimation or measurement. Arch. Phys. Anthropol. Oceania 11, 70–74.

Larnach, S.L., Macintosh, N.W.G., 1966. The Craniology of the Aborigines of Coastal New South Wales. In: Oceania Monographs, vol. 13 Sydney.

Larnach, S.L., Macintosh, N.W.G., 1970. The Craniology of the Aborigines of Queensland. In: Oceania Monographs, vol. 15 Sydney.

Larnach, S.L., Macintosh, N.W.G., 1974. A comparative study of Solo and Australian Aboriginal crania. In: Elkin, A.P., Macintosh, N.W.G. (Eds.), Grafton Elliot Smith: the Man and His World. Sydney University Press, pp. 95–102.

Le Blanc, S.A., Black, B., 1974. A long term trend in tooth size in the eastern Mediterranean. Am. J. Phys. Anthropol. 41, 417–422.

Lekovic, G.P., Baker, B., Lekovic, J.M., Preul, M.C., 2007. New world cranial deformation practices: historical implications for pathophysiology of cognitive impairment in deformational plagiocephaly. Neurosurgery 60, 1137–1146.

Lestrel, P.E., 1997. Fourier Descriptors and Their Applications in Biology. Cambridge University Press, Cambridge.

Lindsell, P.A., 2001. Bergmann, Allen and Birdsell: Patterns of Ecogeographic Adaptation in Aboriginal Australians. Ph.D. Dissertation, University of New England.

Lycett, S.J., Collard, M., 2005. Do homoiologies impede phylogenetic analyses of the fossil hominids? An assessment based on extant papionin craniodental morphology. J. Hum. Evol. 49, 618–642.

Macgillivray, J., 1852. Narrative of the Voyage of HMS Rattlesnake, vol. 2 London.

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007

Macintosh, N.W.G., 1952a. The Cohuna cranium: history and commentary from November 1925 to November 1951. Mankind 4, 307–329.

Macintosh, N.W.G., 1952b. The Cohuna cranium: teeth and palate. Oceania 23, 45–55.

Macintosh, N.W.G., 1971. Analysis of an Aboriginal skeleton and a pierced tooth necklace from Lake Nitchie, Australia. Anthropologie 9, 49–62.

Macintosh, N.W.G., Larnach, S.L., 1976. Australian Aboriginal affinities looked at in world context. In: Kirk, R.L., Thorne, A.G. (Eds.), The Origin of the Australians. Australian Institute of Aboriginal Studies, Canberra, pp. 113–126.

Macumber, P.G., Thorne, R., 1975. The Cohuna cranium site – a reappraisal. Arch. Phys. Anthropol. Oceania 10, 65–70.

Manriquez, G., Gonzales-Bergas, F.E., Salinas, J.C., Espoueys, O., 2006. Intentional cranial deformation in archaeological populations of Arica (Chile): preliminary geometric morphometrics analysis using craniofacial radiographs. Chungara-Revista de Antropologia Chilena 38, 13–34.

Marquez, S., Mowbray, K., Sawyer, G.J., Jacob, T., Silvers, A., 2000. A new fossil hominin calvaria from Indonesia-Sambungmacan 3. Anat. Rec. 262, 344–368.

Martin, R., Saller, K., 1957. Lehrbuch der Anthropologie. Gustav Fischer Verlag, Stuttgart.

Miklouho-Maclay, N., 1882. Cranial deformation of new-born children at the island of Mabiak. Proc. Linn. Soc. New South Wales 6, 627–629.

Moloy, H.C., 1942. Studies on head molding during labor. Am. J. Obstet. Gynecol. 44, 762–782.

Mosimann, J.E., 1975. Statistical problems of size and shape. I. Biological applications and basic theorems. In: Patil, G.P., Kotz, S., Ord, K. (Eds.), Statistical Distributions in Scientific Work. D Reidel, Dordrecht, pp. 187–217.

Mosimann, J.E., James, F.C., 1979. New statistical methods for allometry with applications to Florida red-winged blackbirds. Evolution 23, 444–459.

Mulvaney, D.J., 1991. Past regained, future lost: the Kow Swamp Pleistocene burials. Antiquity 65, 12–21.

Mulvaney, J., Kamminga, J., 1999. Prehistory of Australia. Allen and Unwin, Sydney.

Neufeld, S., Birkett, S., 2000. What to do about flat heads: preventing and treating positional occipital flattening. Axone 22, 29–31.

Özbek, M., 2001. Cranial deformation in a subadult sample from Degirmentepe (Chalcolithic, Turkey). Am. J. Phys. Anthropol. 115, 238–244.

O'Brien, T., Sensor, K., 2004. On the classification of abnormal head shape: interpreting artificial cranial deformation and craniosynostosis. J. Paleopathol. 16, 27–51.

O'Connell, J.F., Allen, J., 2004. Dating the colonization of Sahul (Pleistocene Australia-New Guinea): a review of recent research. J. Archaeol. Sci. 31, 835–853.

O'Dea, K., Patel, M., Kubisch, D., Hopper, J., Traianedes, K., 1993. Obesity, diabetes, amd hyperlipidemia in a central Australian Aboriginal community with a long history of acculturation. Diabetes Care 16, 1004–1010.

O'Higgins, P., Jones, N.B., 1998. Facial growth in *Cercocebus torquatus*: an application of three-dimensional geometric morphometric techniques to the study of morphological variation. J. Anat. 193, 251–272.

Pardoe, C., 2006. Becoming Australian: evolutionary processes that structure biological variation from origin to modern times. Before Farming (on-line version) 2006/1 Article 4.

Pate, F.D., Pretty, G.L., Hunter, R., Tuniz, C., Lawson, E.M., 1998. New radiocarbon dates for the Roonka Flat Aboriginal burial ground, South Australia. Aust. Archaeol. 46, 36–37.

Pechenkina, E.A., Benfer, R.A., Wang, Z., 2002. Diet and health changes at the end of the Chinese Neolithic: the Yangshao/Longshan transition in Shaanxi Province. Am. J. Phys. Anthropol. 117, 15–36.

Perez, S.I., 2007. Artificial cranial deformation in South America: a geometric morphometrics approximation. J. Archaeol. Sci. 34, 1649–1658.

Phenice, T.W., 1969. A newly developed visual method of sexing the os pubis. Am. J. Phys. Anthropol. 30, 297–301.

Pietrusewsky, M., 1971. Application of distance statistics to anthroposcopic data and a comparison of results with those obtained by using discrete traits of the skull. Archaeol. Phys. Anthropol. Oceania 6, 21–33.

Pietrusewsky, M., 1984. Metric and non-metric cranial variation in Australian Aboriginal populations compared with populations from the Pacific and Asia. Occ. Papers Hum. Biol. 3, 1–113.

Pretty, G.L., 1977. The cultural chronology of Roonka Flat. A preliminary consideration. In: Wright, R.V.S. (Ed.), Stone Tools as Cultural Markers. Australian Institute of Aboriginal Studies, Canberra, pp. 288–331.

Ray, L.J., 1959. Metrical and non-metrical features of the clavical of the Australian Aboriginal. Am. J. Phys. Anthropol. 17, 217–226.

Rhode, M.P., Arriaza, B.T., 2006. Influence of cranial deformation on facial morphology among prehistoric South central Andean populations. Am. J. Phys. Anthropol. 130, 462–470.

Richards, L.C., Brown, T., 1981. Dental attrition and degenerative arthritis of the temporomandibular joint. J. Oral Rehab 8, 293–307.

Rightmire, G.P., 1990. The Evolution of *Homo erectus*: Comparative Anatomical Studies of an Extinct Human Species. Cambridge University Press, Cambridge.

Rightmire, G.P., Lordkipanidze, D., Vekua, A., 2006. Anatomical descriptions, comparative studies and evolutionary significance of the hominin skulls from Dmanisi, Republic of Georgia. J. Hum. Evol. 50, 115–141.

Robertson, S., 2007. Sources of bias in the Murray Black Collection: implications for palaeopathological analysis. Aust. Ab. Stud. 2007 (1), 116–130.

Roche, A., 1964. Aural exostoses in Australian Aboriginal skulls. Ann. Otol. Rhinol. Laringol. 73, 82–91.

Ruff, C.B., Trinkaus, E., Holliday, T.W., 1997. Body mass and encephalization in Pleistocene *Homo*. Nature 387, 173–176.

Santa Luca, A.P., 1980. The Ngandong Fossil Hominids. Department of Anthropology Yale University, New Haven.

Schijman, E., 2005. Artificial cranial deformation in newborns in the pre-Columbian Andes. Childs Nerv. Sys. 21, 945–950.

Simpson, J.J., Grun, R., 1998. Non-destructive gamma spectrometric U-series dating. Quatern. Sci. Rev. 17, 1009–1022.

Skrzat, J., Brzegowy, P., Walocha, J., 2002. Computed tomographic assisted study of morphological changes in the sutural areas as resulting from obliteration. Folia Morphol. 257–259, 257–259.

Slice, D., 2007. Geometric morphometrics. Ann. Rev. Anthropol. 36, 261–281.

Stringer, C., 1998. A metrical study of the WLH-50 Calvaria. J. Hum. Evol. 34, 327–332.

Sunderland, S., Ray, L.J., 1959. A note on the Murray Black collection of Australian Aboriginal skeletons. Proc. R. Soc. Victoria 71, 45–58.

Swisher, C.C., Rink, W.J., Antón, S.C., Schwarcz, H.P., Curtis, G.H., Suprijo, A., Widiasmoro, 1996. Latest *Homo erectus* of Java: potential contemporaneity with *Homo sapiens* in Southeast Asia. Science 274, 1870–1874.

Tabachnick, B.G., Fidell, L.S., 2001. Using Multivariate Statistics, fourth ed. Allyn and Bacon, Boston.

Teichgraeber, J.F., Ault, J.K., Baumgartner, J., Waller, A., Messersmith, M., Gateno, J., Bravenec, B., Xia, J., 2002. Deformational posterior plagiocephaly: diagnosis and treatment. Cleft Palate-Cran. J. 39, 582–586.

Teichgraeber, J.F., Seymour-Dempsey, K., Baumgartner, J.E., 2004. Molding helmet therapy in the treatment of braxhycephaly and plagiocephaly. J. Craniofac. Surg. 15, 118–123.

Thorne, A.G., 1975. Kow Swamp and Lake Mungo. Ph.D. Dissertation, University of Sydney.

Thorne, A.G., 1976. Morphological contrasts in Pleistocene Australians. In: Kirk, R.L., Thorne, A.G. (Eds.), The Origin of the Australians. Australian Institute of Aboriginal Studies, Canberra, pp. 95–112.

Thorne, A.G., 1977. Separation or reconcilliation? Biological clues to the development of Australian society. In: Allen, J., Golson, J., Jones, R. (Eds.), Sunda and Sahul. Academic Press, London, pp. 187–204.

Thorne, A.G., 1981. The arrival and adaptation of Australian Aborigines. In: Keast, A. (Ed.), Ecological Biogeography of Australia. Dr. W. Junk, The Hague, pp. 1749–1760.

Thorne, A.G., 1984. Australia's human origins – how many sources? Am. J. Phys. Anthropol. 63, 227.

Thorne, A.G., Grün, R., Mortimer, G., Spooner, N., Simpson, J., McCulloch, M., Taylor, L., Curnoe, D., 1999. Australia's oldest human remains: age of the Lake Mungo 3 skeleton. J. Hum. Evol. 36, 591–612.

Thorne, A.G., Macumber, P.G., 1972. Discoveries of Late Pleistocene man at Kow Swamp. Nature 238, 316–319.

Thorne, A.G., Wilson, S.R., 1977. Pleistocene and recent Australians: a multivariate comparison. J. Hum. Evol. 6, 393–402.

Thorne, A.G., Wolpoff, M.H., 1981. Regional continuity in Australasian Pleistocene hominid evolution. Am. J. Phys. Anthropol. 55, 337–349.

Torres-Rouff, C., 2002. Cranial vault modification and ethnicity in Middle Horizon San Pedro de Atacama, Chile1. Curr. Anthropol. 43, 164–178.

Trotter, M., Gleser, G.C., 1952. Estimation of stature from long bones of American Whites and Negroes. Am. J. Phys. Anthropol. 10, 463–514.

Tubbs, R.S., Salter, E.G., Oakes, W.J., 2006. Artificial deformation of the human skull: a review. Clin. Anat. 19, 372–377.

Washburn, S.L., 1948. Sexual differences in the pubic bone. Am. J. Phys. Anthropol. 6, 199–208.

Webb, S., 1989. The Willandra Lakes Hominids. Department of Prehistory, Australian National University, Canberra.

Webb, S., 1995. Palaeopathology of Aboriginal Australians. Cambridge University Press, Melbourne.

Weidenreich, F., 1943. The skull of *Sinanthropus pekinensis*: a comparative study of a primitive hominid skull. Palaeont. Sinica D10, 1–485.

Weidenreich, F., 1945. Giant early man from Java and South China. Anthropol. Pap. Am. Mus. Nat. Hist. 40, 1–134.

Weidenreich, F., 1951. Morphology of solo man. Anthropol. Pap. Am. Mus. Nat. Hist. 43, 205–290.

Wharton, W.J. (Ed.), 1893. Captain Cook's Journal during His First Voyage Round the World Made in H.M. Bark "Endeavour". Elliot Stock, London.

Widianto, H., Zeitoun, V., 2003. Morphological description, biometry and phylogenetic position of the skull of Ngawi 1 (East Java, Indonesia). Int. J. Osteoarchaeol. 13, 339–351.

Wolpoff, M.H., Hawks, J., Frayer, D.W., Hunley, K., 2001. modern human ancestry at the peripheries: a test of the replacement theory. Science 291, 293–297.

Wunderly, J., 1943. The Keilor fossil skull: anatomical description. Mem. Nat. Mus. Victoria 13, 57–69.

Yokoyama, Y., Falguères, C., Sémah, F., Jacob, T., Grün, R., 2008. Gamma-ray spectrometric dating of late *Homo erectus* skulls from Ngandong and Sambungmacan, Central Java, Indonesia. J. Hum. Evol. 55, 274–277.

Young, R.W., 1957. Postnatal growth of the frontal and parietal bones in white males. Am. J. Phys. Anthropol. 15, 367–386.

Please cite this article in press as: Brown, P., Nacurrie 1: Mark of ancient Java, or a caring mother's hands, in terminal Pleistocene Australia?, J Hum Evol (2010), doi:10.1016/j.jhevol.2010.05.007