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Forensic Anthropology Population Data

In vivo facial soft tissue thicknesses of adult Australians☆

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ABSTRACT

Facial soft tissue thicknesses (FSTT) set important quantitative guides in craniofacial identification, but so far Australian FSTTs have only been published for supine cadavers. This study aimed to use B-mode ultrasound to measure FSTTs in living Australians (N = 63 participants; $n_1 = 52$ [$\bar{x} = 21$ years, $s = 2$ years]; and $n_2 = 11$ [$\bar{x} = 54$ years, $s = 13$ years]) using 14 craniometric landmarks with participants in both upright and supine positions. The multiple pre-existing Australian cadaver investigations (n = 7 reporting FSTT means and 6 of these reporting raw datasets) enabled living and cadaveric samples drawn from the same parent population to be compared. By using a non-invasive and safe imaging method (no ionising radiation) repeated measurements could be taken in the *in vivo* participants to gauge measurement reliability (and compare to pre-existing reliability for cadaver measurements): mean r-TEM = 12%; max r-TEM = 25%. In terms of changes between upright and supine positions (as measured by B-mode ultrasound) only 2 of 14 measured landmarks had FSTT changes in excess of 1 mm. Comparisons of the *in vivo* ultrasound data to pre-existing needle puncture studies demonstrated that mean B-mode ultrasound measurements were very similar to cadaver values. Contrary to popular thought, but in keeping with the findings of prior meta-analyses, cadaver FSTT data are good proxies to living subjects, at least as measured by ultrasound. To increase sample sizes and triangulate upon ground truth FSTT values, weighted grand means combining all Australian samples were calculated (n range = 280–385) and compared to the multi-group 2018 adult T-Tables (max. n = 10,333).

1. Introduction

The generic thickness of the facial soft tissue envelope around the skull, and how it varies between individuals, provides important information for the estimation of facial appearance from the skull (facial approximation) [1,2], or comparison of skull and face photographs for anatomical correspondence (photographic/video superimposition) [3,4]. These facial soft tissue thicknesses (FSTT) can be measured using a variety of measurement techniques ranging from the insertion of needles or blades in cadavers [5–8] to more sophisticated technological approaches of: radiography/CT [9–12], magnetic resonance imaging [13–15], and ultrasound [3,16,17].

Typically, FSTT measurements are taken at a number of select anatomical landmarks located sparsely around the face [18]. So far, there has been a total of seven investigations of FSTTs of adult Australians and all have used needle puncture methods on cadavers: [19–24], [25] cited in [26] (Table 1). There has been no documented measurement of the FSTTs in living Australians despite a preference for such data in the mainstream literature due to a common perception that facial soft tissues change following death [16,22,27–32], making them misleading if used for living subjects.

In living subjects, facial soft tissue thicknesses can be measured using radiographs, MRI or ultrasound [22]. Ultrasound has become popular because it is relatively inexpensive, non-invasive, does not expose the participant to ionising radiation, and can be used to measure subjects in the upright posture as applicable to craniofacial casework [3,16–18,27,33,34]. Brightness or B-mode ultrasound supplies a dynamic on-screen image that enables the skull and skin surfaces to be visualized, assisting measurement and making it one of the preferred approaches [16,17,33].

While the collection of data in upright living subjects is important [3,16–18,27,33,34], it is equally useful to empirically test and validate the utility of this data (over and above its cadaveric counterparts) so that the physical reality of any postulated benefits of *in vivo* FSTT data can be verified. While differences between

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Table 1
Prior FSTT studies, by year of conduction, on Australian cadavers.

Author	Sutton [21]	Forrest [19]	O'Grady et al. [25] cited in [26]	Anderson [24]	Simpson and Henneberg [22]	Simpson and Henneberg [22]	Sutisno [20]	Domaracki and Stephan [23]
Year	1969	1985	1990	1996	2002	2002	2003	2006
Study location	Melbourne	Brisbane	Melbourne	Adelaide	Adelaide	Adelaide	Sydney	Adelaide
Ancestry[a]	European stock	White caucasions	Not reported (acAW)	Not reported (acAW)	White Australian	White Australian	Caucasoid	European extraction
Needle puncture method	42 mm long, 26 gauge, hypodermic needle with 4 g weight on cork plunger	27 gauge hypodermic needle with rubber disc plunger	Hypodermic needle with rubber disc plunger	Hypodermic needle with rubber disc plunger	Size 35 Beutelrock Finger Pluggers Dental Needle with rubber disc plunger	Size 35 Beutelrock Finger Pluggers Dental Needle with rubber disc plunger	27 gauge hypodermic needle with rubber disc plunger	46 mm long regular sewing pin — sooted
Cadaver status	Embalmed	Unembalmed	Embalmed	Embalmed	Embalmed	Unembalmed (12 h PM)	Unembalmed (<36 h PM)	Embalmed
Males Age (years) N	104	23	51	28	30	9	150	33
n	69	14	24	28	13	4	88	19
Range	–	13–76	–	54–92	59–82	79–94	18–94	64–95
$\bar{x}$	>Middle age	46.4	–	–	76.6	84.5	63.9	79.7
s	–	20.9	–	–	6.6	7.1	18.1	9.4
Females Age (years) n	35	9	27	–	17	5	62	14
Range	–	21–86	–	–	52–100	74–101	31–94	46–89
$\bar{x}$	>Middle age	55.4	–	–	76.4	84.0	65.0	74.2
s	–	17.3	–	–	13.7	11.9	16.9	12.2
# of landmarks examined	Only zygion (zy–zy′)	22	18	20	20	20	24	13

acAW = almost certainly Australian Whites.
[a] Using terminology stated by the original publishing authors.

living and deceased subjects are seemingly intuitive, it is possible that the differences are more complex than appreciated at first glance and in practice may not adhere so well to preconceived notions. For example, a range of factors complicate the sensitivity of FSTT data measurement and these may hamper attempts to detect differences between living and deceased states of subjects: changes following death may be subtle and only manifest from their multivariate combination [35]; sparse location of FSTT collection sites around the face make detection of small localised shape changes upon death difficult [35]; large FSTT measurement errors (up to 30%) may obfuscate the detection of differences using popular measurement tools [36]; and confounding effects of supine position in cadaveric datasets may obfuscate other differences between cadaver and living state [36]. For these reasons, it is important to conduct tests to provide metric clarity.

2. Materials and methods

In this study, FSTTs were measured in 64 living Australians (Table 2 and Fig. 1) using a portable MindRay® DP-50 B-mode ultrasound system with a MindRay® 10L24EA 10 Hz linear surface transducer (Shenzen, China). This overarching sample (N = 64) comprised two study cohorts, one of 53 subjects (n_1; mean age = 21 years, s = 2 years, range = 18–30 years of age) and a smaller subset of 11 older individuals (n_2; mean age = 54 years, s = 13 years, range = 37–74 years), the latter of which served as a focus group for studying any exaggerated effects of soft tissue movement in older adults who potentially possessed more mobile skin.

Generous gel standoff platforms were employed to mitigate ultrasound transducer pressure on the skin [36], thereby minimizing soft tissue compression during measurement (Fig. 2). The 10 Hz linear transducer was also specifically chosen to provide a good compromise between depth of sound-wave penetration and resolution.

Table 2
This study's sample details.

Dataset	Variable	Males Mean	Males s	Females Mean	Females s
18–30 years old (n_1)	Age (years)	21.6	2.5	20.6	2.1
	Height (mm)	1817.2	52.6	1668.0	56.8
	Mass (kg)	80.5	12.5	62.0	8.3
	BMI (m/kg^2)	24.3	3.0	22.2	2.5
>37 years old (n_2)	Age (years)	52.5	15.8	55.0	11.8
	Height (mm)	1770.5	96.0	1630.9	47.4
	Mass (kg)	84.8	15.0	71.2	13.9
	BMI (m/kg^2)	26.9	2.7	26.8	5.4

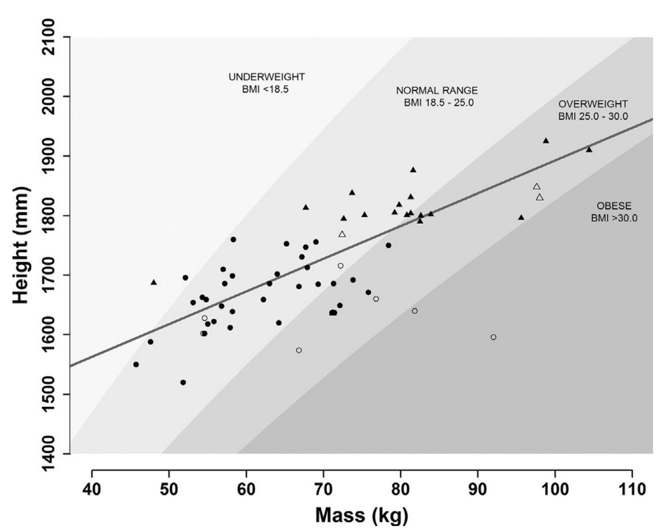

Fig. 1. Scatterplot of sample by height (mm) and mass (kg) with World Health Organization BMI groupings in background [44]. n_1: ● = females, 18–30 years; ▲ = males, 18–30 years. n_2: ○ = females, >37 years; △ = males, >37 years. Regression line is fitted to n_1 data for the 18–30 year olds. Graph generated in R [45] using the *BodyPlot* script available at CRANIOFACIALidentification.com [46].