Variation Of the Human Skull Bone Thickness with the Age, Gender, and Body Stature: An Autopsy Study of the Sri Lankan Population

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Abstract
Introduction: Many characteristics of the skull bones used in identification are subjective. Since the human skull thickness (HST) can be used as a more objective criterion, it can be used in more accurate identification in forensic anthropology, and according to literature; no such studies were conducted in Sri Lanka. The aim of this study is to assess the thickness of individual skull bones and the association of the HST with age, gender, and body stature.

Methods: A cross-sectional analytical study was carried out among 100 autopsies selected randomly at the National Hospital Kandy, and Teaching Hospital Peradeniya, Sri Lanka. Socio-demographic profile was collected using an interviewer-administered questionnaire; bone thickness was measured using a calibrated vernier caliper and body height was measured using a measuring tape. The association between bone thickness with age and body stature was assessed using the Pearson linear correlation. The association of bone thickness with gender was calculated with Chi-square.

Results: The mean skull bone thicknesses obtained were temporal (4.7mm on both), parietal (6.1mm on right and 5.8mm on left), occipital (7.2mm on right and 6.4mm on left), and frontal (8.8mm), with the frontal bone being the thickest among both males and females. Skull bone thickness showed a significant difference with gender in occipital and frontal bones. Only the left temporal bone thickness showed a small positive correlation with age. HST showed no correlation with body stature.

Conclusion: This study shows that there are variations in HST with gender and no correlation with body stature.

Keywords: Autopsy, bone thickness, forensic anthropology, skull bone

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Introduction

The human skull is a bony structure comprising of 22 bones and forms a protective cavity for the brain. Skull consists mainly of occipital, temporal, parietal, frontal, sphenoid bones, and ethmoid bones.[1] In Sri Lanka, cranial injuries are seen in both accidents and assaults, which are warranted for clinical forensic examination as well as for autopsy. Human Skull thickness (HST) is a factor that directly affects the severity of the intracranial injuries as skull deformation occurs due to the force of trauma.[2] Therefore many studies have been done with regard to HST with imaging techniques, such as magnetic resonance imaging (MRI), Computerized tomography (CT) scan, and Ultra sound scan (USS).[3-8] However, few have been done with autopsy material.[9-11] Literature reveals no studies which have been conducted in Sri Lanka in either option.

Medico-legal identification of the HST variations can be important in anticipating the severity of the intracranial injuries and determining the type of the injury. According to the Annual Health Bulletin in Sri Lanka for the year 2019, traumatic injuries are the leading cause of hospitalization and the 10th leading cause of hospital deaths.[12] According to the indoor morbidity and mortality report in Sri Lanka in the year 2019 intracranial injuries account for 3526 males and 1664 females in live discharges following hospitalization and 519 male and 187 female deaths due to intracranial injuries.[13]

Skull and pelvis are the main structures used in identification in forensic anthropology. Subjective features like robustness, shape, areas of muscle attachment, smoothness, and gracility play significant weight in identification.[14] HST is an objective measurement that can be used in anthropology. According to a study done on the diploeic thickness of the skull bones conclude that there is a significant difference in diploeic thickness between males and females in the frontal region only. Diploeic thickness was highly correlated with total cranial vault bone thickness.[10]

Bone density is defined as the amount of bone minerals in bone tissues, which is directly related to bone mass.[15] Whether the bone density is directly related to bone strength or not; the association with bone thickness is not well established. Factors affecting bone density are age, gender, Vitamin D deficiency, Calcium deficiency, hormonal imbalances, food habits, and physical exercise.[16] Variation of HST is studied in this research since it is a less-explored topic in relation to autopsy subjects in Sri Lanka.

Therefore, the aim of this study is to assess the thickness of skull bones and the association of the HST with age, gender, and body stature in autopsies carried out at the National Hospital, Kandy (NHK) and Teaching Hospital, Peradeniya (THP), Sri Lanka.

Methodology

After excluding deaths with head injuries and history of chronic illness, conditions affecting skull thickness or anatomy of the skull, unknown cadavers, and cadavers with extreme putrefaction with skeletonization, 100 cases were selected at NHK and THP for this cross-sectional analytical study. The socio-demographic profile of the subjects was collected from the legal guardian using an interviewer-administered questionnaire. Information related to the past medical history, chronic conditions, and circumstances of the death was collected from medical records, medico-legal documents, and police reports. The height of the subjects was measured with a measuring tape of the brand "Juneng" attached to a special apparatus to measure the height of the cadaver.

HST was measured after removing the skull vault with V shape dissection starting from the midline of the frontal bone to the 3cm above the zygomatic process vertically upwards to the mastoid process and ending up in the posterior aspect of the skull in the midline, 1cm below the fusion of the sagittal suture with a lambdoid suture. The thickness of the temporal bone was measured bilaterally 3cm vertically above the zygomatic process in the remaining skull base attached to the body. The thicknesses of the occipital bone, parietal bone, and frontal bone were measured in the vault of the skull, which was removed from the body. Frontal bone thickness was measured in the midline of the frontal bone. Occipital bone thickness was measured bilaterally 1cm apart from the midline posteriorly, parietal bone thickness was measured bilaterally 4cm apart from the midline posteriorly.

A digital vernier caliper which was supplied by Sigma Chemical, Sri Lanka was used to measure bone thickness, and measurements were taken up to two decimal points in millimeters. To minimize the observer error, the principal investigator took the measurements and used the same equipment and procedure to collect data throughout the entire study.

Collected data were entered into Microsoft Excel worksheets and analyzed using Statistical Package for Social Sciences (SPSS). Bone thickness was expressed as mean and standard deviations. A Chi-square test was used to determine the association of bone thickness with gender while Pearson linear correlation was used to determine the association of HST with age and body stature. The confidence level of 95% was selected to decide statistical significance, while a cut-off value of 0.05 was used to determine the statistical significance.

Results

This study was conducted by measuring the HST of 100 cadavers and the results were categorized according to the physical and demographic features of the subjects.

1. Description of the study population

Out of the 100 study subjects, 55 (55%) were males while 45 (45%) were females. The majority of the subjects were in the age group of 61-70 years (45%), followed by the age groups of 51-60 years (32%), 41-50 years (9%), 31-40 years (7%) and 18-30 years (7%).

When considering the body stature of the subjects, 99% of them were categorized into three height groups of more than 160 cm (62%) and 159-140 cm (37%). Only one of the subjects measured less than 140 cm in height.

2. Distribution of the mean thickness of individual skull bone among autopsies

According to this study temporal bone was the thinnest bone, with a mean thickness of 4.7mm each on both sides, and the frontal bone was the thickest bone, with a mean thickness of 8.8mm, followed by the occipital (7.2mm on right and 6.4mm on left) and parietal bones (6.1mm on right and 5.8mm on left).

3. Distribution of the HST according to sex

Frontal bone was of the highest thickness in both males and females. Temporal bone had the lowest mean thickness in both males and females. When comparing the gender, females had a greater skull bone thickness than males.

In this population, when the thickness of each skull bone was compared among males and females, there are statistically significant differences in occipital and frontal bones (Table 1).

Table 1: Description of the mean individual skull bone thickness according to gender

Skull Bone	Equal variances assumed P value	Mean bone thickness (mm)	Sex
R/S Temporal	0.922386	4.555227	Female
		4.535091	Male
L/S Temporal	0.40545	5.095909	Female
		4.882364	Male
R/S Parietal	0.110258	6.129545	Female
		5.714182	Male
L/S Parietal	0.429078	6.201591	Female
		6.002909	Male
R/S Occipital	0.039149	7.268636	Female
		6.548545	Male
L/S Occipital	0.007887	7.260909	Female
		6.416182	Male
Frontal	0.000617	9.482727	Female
		8.252691	Male

In females, the thickness of frontal, occipital, parietal, and temporal bone thicknesses initially decreases in the groups 40-49 years to 50-59 years and then shows an increase with age in the age group of 60-70 years (Fig. 1).

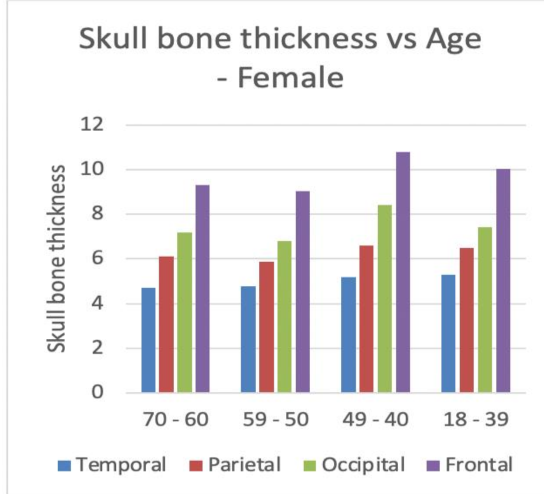

Figure 1: Variation of HST in age groups in females

Similar to females, males also show initially a decrease and then an increase in HST in the age groups, only in the frontal bone. In occipital bone, bone thickness decreases along with the age groups in males. In parietal bone, there is an initial increase and then a slight decrease in thickness along with age groups. Temporal bone shows an increase in bone thickness in males along with increasing age groups (Fig. 2).

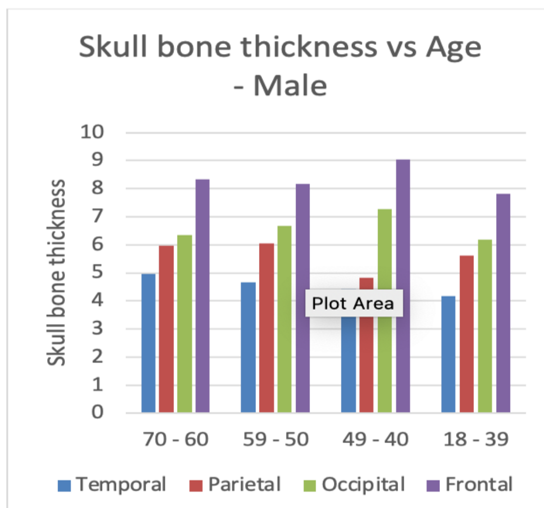

Figure 2: Variation of HST in age groups in males

4. Relationship of individual skull bone with age.

When each individual skull bone thickness was compared with age, the derived p-value was less than 0.05. Therefore, in each skull bone, there is a statistically significant variation in thickness with age.

5. Relationship of individual skull bone with body stature and age.

When the average thickness of each bone is compared with age and height using Pearson linear correlation, only the left temporal bone showed a small positive correlation with age while the right occipital bone showed a small positive correlation with height. Other bones showed no correlation with age or height (Table 2).

Table 2: Correlation of average HST with body stature and age

	Skull Bone thickness						
Correlation	R/S Temporal	L/S Temporal	R/S Parietal	L/S Parietal	R/S Occipital	L/S Occipital	Frontal
With age	0.039133	0.190718	0.011316	0.036143	-0.03915	-0.05694	-0.05969
With height	0.032646	-0.00747	0.077994	0.095283	0.1467	0.087475	-0.07423

When considering the average bone thickness, frontal bone thickness shows a decrease with body stature in groups. Other bones show no such significant difference in bone thickness with body stature (Fig. 3).

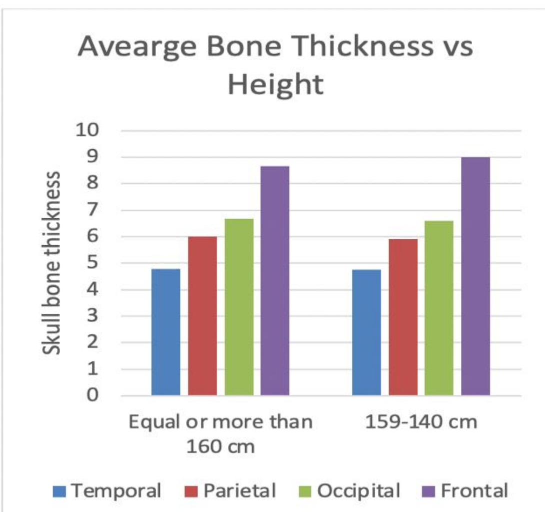

Figure 3: Variation of average bone thickness with body stature

Discussion

This study analyses the relationship between the thickness of the human skull bones and age, gender, and body stature, with the aim of formulating an objective association to be used in forensic anthropology.

Several previous studies suggest that frontal and occipital bones are the thickest skull bones. In an autopsy study done in Malaya, it was concluded that the occipital bone was the thickest skull bone, while the frontal bone was found to be the second thickest skull bone.[11] In a study done using magnetic calipers, the occipital bone was found to be the skull bone with the highest mean thickness value, followed by the frontal, parietal, and temporal bones.[17] A 2021 study conducted on living subjects concluded that occipital and parietal bones were the thickest in the skull.[18] Our study also showed similar results with frontal and occipital bones being the thickest.

As in our study, a single center study done using CT scan measurements revealed that the female calvarium is significantly thicker than in males.[3] A 2021 study on live subjects further revealed that females have a thicker frontal bone.[18] A retrospective survey of 1097 Dutch autopsy cases revealed that adult females have larger frontal bone thickness.[9] In a study assessing diploeic thickness, there was a statistically significant difference in diploeic thickness between males and females in the frontal region only.[10] Previous studies have shown that females have thicker skull bones which is partially influenced by the presence of age-related changes such as hyperostosis frontalis interna (HFI) which is the marked endocranial increase in thickness of the frontal bone and more frequent in post-menopausal females.[19]

In the study sample, 77% of the subjects were aged more than 50 years and 45% of the study population were females. Since HFI has only a partial influence on skull thickness, it could be a possible cause of females having greater HST, especially in the frontal bone.

Bone growth and remodeling are affected by the systemic and mechanical loading of the body. The facts that the skull is not a bone with mechanical and exercise-induced remodeling and reduced grey matter with aging can affect the thickness of the skull bone.[4] Although our study showed a correlation with age, another study conducted by Lynnerup in a Danish forensic sample revealed no correlation between age and cranial thickness, adding to other studies showing that cranial thickness cannot be used in aging or sexing human remains.[10, 20] However a study done by Lillie et al shows there is a gradual increase in bone thickness with age and it was more pronounced in the frontal and parietal regions of the skull.[4] So complex variations can be seen within studies and further studies with larger study samples with wider distribution within age groups will provide more statistical significance to assess the age-related skull bone thickness variation.

Determination of the biological profile of an individual is important in identification. The relationship of HST with stature is an ongoing discussion in forensic anthropology. According to our study, HST shows no correlation with body stature. Similarly, a study done in the Netherlands with 1097 autopsies shows no correlation of HST with body stature.[9] Another study done with Caucasian patients using CT scans shows femur gave a great correlation than the skull in stature estimation.[21] Many such studies fail to reveal a correlation of body stature with HST which is compatible with our study.

In this study, a standard vernier caliper was used for cranial vault measurements. A study conducted to compare the use of traditional and magnetic calipers had shown that the measurements from magnetic calipers are more reliable and effective where the endocranial surface is not easily accessible, and where expensive technologies like CT scanning are not available.[17] During an autopsy, the skull vault is usually opened by a skull saw. This process can impede the HST measurements since irregular cuts can be encountered during cutting the skull vault open. The dimensions of the frontal sinus were not taken into consideration when measuring the frontal bone thickness. A 2010 study conducted using computed tomography imaging and a 2021 Turkish study revealed that males have significantly larger frontal sinuses.[18, 22] Therefore it is advisable to consider any errors caused by variations in dimensions of the frontal sinus in future studies. To measure the size of the frontal sinus, ante-mortem and post-mortem imaging modalities can be employed.

The other measurement taken for this study, the height of the subjects was measured using a tape designed to measure cadavers. A preliminary study conducted in 2017 shows that there can be a slight increase in body length from 2 hours to 24 hours after death.[23] Another study conducted in 2005 shows that there can be a statistically significant but practically insignificant change in post-mortem body height and no change due to rigor mortis.[24] These facts can be considered in this study by recording the post-mortem body length at several time intervals, in contrast to measuring the body height once as in this case. More accurate and reliable body length measuring devices, such as the novel device of post-mortem body length measurement introduced in 2016, can be used to minimize errors during measurement.[25]

Conclusions

This study shows that there are variations in skull bone thickness with gender and no correlation with body stature. Further studies with a larger study population would provide an opportunity to assess determinants of skull bone thickness better.

Disclosure statement

Conflicts of Interest: The authors declare that they have no conflicts of interest.

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